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(54) **CUTTING TOOL**

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Description

TECHNICAL FIELD

[0001] The present invention relates to a cutting tool obtained by forming a coating layer on the surface of a substrate.

BACKGROUND ART

[0002] With a cutting tool requiring abrasion resistance, sliding properties and fracture resistance, there have currently been used techniques of forming a variety of coating layers on the surface of a hard substrate made of WC-based cemented carbide, TiCN-based cermet or the like, to improve the abrasion resistance and the fracture resistance of the cutting tool.

[0003] While a TiCN layer or a TiAlN layer have been generally and broadly used as such a coating layer, there have been development of a variety of coating layers with the aim of further improving the abrasion resistance and fracture resistance.

[0004] For instance, Patent Document 1 discloses a throwaway insert where a value of a ratio I(200)/I(111) of a diffraction intensity 1(200) of a plane (200) to a diffraction intensity I(111) of a plane (111) in X-ray diffraction of a TiAl composite compound layer that coats the surface of the substrate is controlled so as not to be smaller than 1. Further, Patent Document 2 discloses a throwaway insert where a value Ib(220)/Ia(111) of diffraction intensities in X-ray diffraction of a TiAl composite compound layer is set within a range of "$1.0 < Ib / Ia \leq 5.0$" for enhancing oxidation resistance and flaking resistance of a coating layer.

[0005] Moreover, Patent Document 3 describes controlling peak intensity ratios of crystal planes (111), (200) and (220) which are measured in X-ray diffraction on a coating layer made of TiAlCr-based composite nitride or carbonitride. It is to be noted that few diffraction peaks of a plane (400) exist in an X-ray diffraction chart illustrated as FIG. 6 in this document. Furthermore, Patent Document 4 describes formation of a laminated structure of a first layer with a crystal plane (200) having the maximum height and a second layer with a crystal plane (111) having the maximum height in a TiAl nitride layer.

[0006] As described in above Patent Documents 1 to 4, it is known that controlling diffraction intensities in X-ray diffraction in the TiAl composite nitride layer to control characteristics of the coating layer, especially controlling the crystal planes (111), (200) and (220) having large diffraction intensities, enhances hardness and oxidation resistance of the coating layer, while also enhancing adhesiveness to the substrate.

Patent Document 1: Japanese Patent Laid Open Publication No. H9-295204

Patent Document 2: Japanese Patent Laid Open Publication No. H9-300106

Patent Document 3: Japanese Patent Laid Open Publication No. 2002-3284

Patent Document 4: Japanese Patent Laid Open Publication No. H10-330914

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0007] There has, however, been a problem with wet cutting performed on a so-called wet condition using cutting oil, especially in milling cutting, in that simply enhancing the hardness and oxidation nature of the coating layer will not lead to improvement in abrasion resistance, but instead, increasing the thickness of the coating layer causes partial flaking of the coating layer, resulting in prevention of the life of the cutting tool from being extended.

[0008] An object of the present invention is to provide a cutting tool having a long tool life even on cutting conditions requiring abrasion resistance and flaking resistance as in wet cutting.

MEANS FOR SOLVING THE PROBLEMS

[0009] A cutting tool according to claim 1 includes a substrate; and a coating layer, which coats the surface of the substrate and is made of nitride or carbonitride containing Ti and Al and in which, when a layer thickness on a flank face is 3 to 9 μm and when a ratio I(400)/I(311) of a diffraction intensity I(400) of a plane (400) to a diffraction intensity 1(311) of a plane (311) concerning a thin film X-ray diffraction peak of Cu-Kα rays is taken as p, p is larger on the outer surface side than on the substrate side.

[0010] Here, when the ratio p is taken as p_s at the time of performing a thin film X-ray diffraction analysis on the outer surface of the coating layer, p_s be 0.2 to 1.

[0011] It is further preferable in the above configuration that, when the ratio p is taken as p_b at the time of performing the thin film X-ray diffraction analysis in a state where a region within a thickness of 1.5 μm from the substrate-side interface of the coating layer is exposed, p_b be 0.1 to 0.5.

[0012] It is further preferable in the above configuration that, when a ratio p_s/p_b of the ratio p_s to the ratio p_b is taken as r, r be 1.5 to 7.

[0013] It is further preferable according to the cutting tool according to the present invention that the coating layer is formed of a lower layer and an upper layer, and when a ratio I(400)/I(311) of a diffraction intensity I(400) of a plane (400) to a diffraction intensity I(311) of a plane (311) concerning an X-ray diffraction peak of Cu-Kα rays of the coating layer on a polished face, formed by polishing the coating layer obliquely to the thickness direction, is taken as P, P_1 measured on an unpolished face of the upper layer be 0.1 to 0.5, P_3 measured in a portion where an interface of the lower layer and the upper layer on the polished face is exposed be smaller than P_2 measured on the polished face of the upper layer, and P_2 be smaller than P_1.

[0014] It is further preferable in the above configuration that a total thickness T_e of the coating layer on the cutting edge be 3 to 15 μm, and a ratio (T_e/T_f) to a thickness T_f of the coating layer at a center position of the flank face be 1.2 to 3.8.

[0015] It is further preferable in the configuration that, when a ratio (t_e/T_e) of a thickness t_e of the lower layer to the total thickness T_e of the coating layer on the cutting edge is taken as A, the ratio A be 0.2 to 0.6, and when a ratio (t_f/T_f) of a thickness t_f of the lower layer to the total thickness T_f of the coating layer at the center position of the flank face is taken as a, a ratio (A/a) of the ratio A to the ratio a be 0.4 to 0.9.

[0016] It is further preferable in the cutting tool according to the present invention that the thickness of the coating layer on the cutting edge be 3 to 10 μm, and when a ratio I(220)/(I(111) + I(200) + I(220) + I(222) + I(400)) as to respective diffraction intensities I(111), I(200), I(220), I(222) and I(400) of planes (111), (200), (220), (222) and (400) concerning a micro X-ray diffraction peak of Cu-Kα rays of the coating layer is taken as q and when a value q on a rake face, a value q on the flank face and a value q on the cutting edge are respectively taken as q_r, q_f and q_e, "$q_e > q_r$" and "$q_e > q_f$" hold.

[0017] Here, it is preferable in the above configuration that "$q_e > q_r > q_f$" hold.

[0018] It is further preferable in the above configuration that, when a ratio I(400)/(I(111) + I(200) + I(220) + I(222) + I(400)) as to the respective diffraction intensities I(111), I(200), I(220), I(222) and I(400) of the planes (111), (200), (220), (222) and (400) of the coating layer is taken as Q and when a value Q on the rake face, a value Q on the flank face and a value Q on the cutting edge are respectively taken as Q_r, Q_f and Q_e, "$Q_r > Q_e > Q_f$" hold.

EFFECTS OF THE INVENTION

[0019] The cutting tool according to the present invention has the significant feature in that the surface of a substrate is coated with a coating layer made of nitride or carbonitride containing Ti and Al and having a thickness of 3 to 9 μm on a flank face, and when a ratio I(400)/I(311) of a diffraction intensity I(400) of a plane (400) to a diffraction intensity 1(311) of a plane (311) concerning a thin film X-ray diffraction peak of Cu-Karays is taken as p, p in the coating layer is larger on the outer surface side than on the substrate side. It is thereby possible to give a cutting tool having high abrasion resistance and high fracture resistance without flaking of the coating layer, thus having long tool life even in wet cutting, especially milling cutting.

[0020] In the above configuration, when the ratio p is taken as p_s at the time of performing a thin film X-ray diffraction analysis on the outer surface of the coating layer, p_s is 0.2 to 1, thereby exerting the effect of enhancing the abrasion resistance of the coating layer.

[0021] Further, in the above configuration, when the ratio p is taken as p_b at the time of performing the thin film X-ray diffraction analysis in a state where a region within a thickness of 1.5 μm from the substrate-side interface of the coating layer is exposed, p_b is 0.1 to 0.5, thereby allowing enhancement of adhesiveness. A particularly preferable range of p_b is from 0.15 to 0.35.

[0022] Moreover, when a ratio $p_{s/}p_b$ of the ratio p_s to the ratio p_b is taken as r, r is 1.5 to 7, thereby allowing balancing of the abrasion resistance, the fracture resistance and the flaking resistance, to achieve an extended life.

[0023] Here, the coating layer may be a coating layer which is formed of a multilayered structure of a lower layer and an upper layer and whose orientation (P_1, P_2 P_3) is controlled. It is thereby possible to provide a cutting tool having high abrasion resistance without flaking of the coating layer, thus having a long tool life even in cutting with a turning tool. In addition, although the reason for the peak intensity ratio between the diffraction peaks of the plane (400) and the plane (311) being related to the adhesiveness of the coating layer is unclear, it is presumed to be associated with internal stress of the coating layer.

[0024] It is to be noted that a total thickness T_e of the coating layer on the cutting edge is 3 to 15 μm, and a ratio (T_e/T_f) to a thickness T_f of the coating layer at a center position of the flank face is 1.2 to 3.8, whereby it is possible to enhance the abrasion resistance without impairing the fracture resistance of the cutting edge.

[0025] It is preferable in the respect of allowing further control on flaking of the coating layer on the cutting edge that, when a ratio (t_e/T_e) of a thickness t_e of the lower layer to the total thickness T_e of the coating layer on the cutting edge is taken as A, the ratio A be 0.2 to 0.6, and when a ratio (t_f/T_f) of a thickness t_f of the lower layer to the total thickness T_f of the coating layer at the center position of the flank face is taken as a, a ratio (A/a) of the ratio A to the ratio a be 0.4 to 0.9.

[0026] Further, according to the cutting tool according to the present invention, it is preferable that the thickness of the coating layer on the cutting edge be 3 to 10 μm, and when a ratio I(220)/(I(111) + 1(200) + 1(220) + I(222) + I(400)) as to respective diffraction intensities I(111), 1(200), 1(220), I(222) and I(400) of planes (111), (200), (220), (222) and (400) concerning a micro X-ray diffraction peak of the Cu-Kα rays of the coating layer is taken as q and when a value q on a rake face, a value q on the flank face and a value q on the cutting edge are respectively taken as q_r, q_f and q_e, "$q_e > q_r$" and "$q_e > q_f$" hold. It is thereby possible to provide a cutting tool having high abrasion resistance without flaking of the coating layer, thus having long tool life even in cutting with a milling tool.

[0027] It should be noted that, although the reason for the peak intensity ratio of the diffraction peak of the plane (220) being related to cutting performance is unclear, it is presumed to be associated with internal stress of the coating layer on the cutting edge located on a cross ridge line section. In other words, it is thought that optimizing an arrangement of a crystal of the cutting edge located on the cross ridge line section of the rake face and the flank face leads to reduction in chipping and flaking of the coating layer on the cutting edge.

[0028] While the rake face and the flank face both require high abrasion resistance, since it becomes impact load at the start of the cutting and at the time of intermittent processing, it is preferable that the chipping resistance and the fracture resistance be not lost.

[0029] It is preferable that "$q_e > q_r > q_f$" hold for improvement in adhesiveness resistance at the time of cutting.

[0030] Further, for allowing an increased thickness without occurrence of chipping or flaking due to impact at the time of cutting, to exert high abrasion resistance, it is preferable that, when a ratio I(400)/(I(111) + I(200) + I(220) + 1(222) + I(400)) as to the respective diffraction intensities I(111), I(200), I(220), I(222) and I(400) of the planes (111), (200), (220), (222) and (400) of the coating layer is taken as Q and when a value Q on the rake face, a value Q on the flank face and a value Q on the cutting edge are respectively taken as Q_r, Q_f and Q_e, "$Q_r > Q_e > Q_f$" hold.

BEST MODE FOR CARRYING OUT THE INVENTION

(First Embodiment)

[0031] An example of the cutting tools according to the present invention will be described with reference to: FIG. 1 as a schematic perspective view concerning a insert section of a throwaway milling tool (hereinafter simply abbreviated as tool) A mounted with a throwaway insert (hereinafter simply abbreviated as insert) as a case in point; FIG. 2 as (a) a schematic perspective view of the insert 1 to be mounted and (b) a plan view of the same; FIG. 3 as a sectional view taken along line a-a of FIG. 2(a) concerning the insert 1 of FIG. 2; and FIG. 4 as an example of thin film X-ray diffraction patterns concerning a coating layer 9 of the insert 1 of FIG. 3 at the time of performing a thin film X-ray diffraction measurement (s) on the outer surface, and (b) in a state where a area with a layer thickness within 1.5 μm from the substrate is exposed.

[0032] According to FIGS. 1 to 3, in the insert 1, a cross ridge line of the principal face forming a rake face 3 and the side face forming a flank face 4 of a substrate 2, with its principal face having a substantially flat shape, forms a cutting edge 8 including a major cutting edge 6 and a minor cutting edge 7 with a corner cutting edge 5 sandwiched therebetween, and the surface of the substrate 2 is coated with a coating layer 9. Further, in the tool A, the insert 1 is mounted in the insert pocket 12 of a holder 11. A screw 13 is inserted into a screw hole 14 formed at the center of the insert 1, and then screwed into the holder 11, and the insert 1 is thereby cramped to the holder 11.

[0033] As shown in FIGS. 3 and 4, the present invention has a significant feature in that the coating layer 9 made of nitride or carbonitride containing Ti and Al and having a thickness of 3 to 9 μm on a flank face is coated, and when a ratio I(400)/I(311) of a diffraction intensity 1(400) of a plane (400) to a diffraction intensity I(311) of a plane (311) concerning a thin film X-ray diffraction peak of Cu-Karays on the coating layer 9 is taken as p, p on the coating layer 9 is larger on the outer surface side than on the substrate 2 side. It is thereby possible to provide a cutting tool having high abrasion resistance and high fracture resistance without flaking of the coating layer, thus having a long tool life even in wet cutting. In particular, it is possible to significantly suppress the development of boundary damage apt to occur at the time of milling cutting.

[0034] More specifically, when the thickness of the coating layer 9 on the flank face is smaller than 3 μm, the abrasion resistance sharply deteriorates and abrasion develops due to noching or the like, whereby the tool reaches the end of its tool life. On the contrary, when the thickness of the coating layer 9 on the flank face exceeds 10 μm, the coating layer 9 is apt to be partially peeled, and the abrasion may develop due to the flaking, causing the tool to reach the end of its tool life at the early stage. A preferable thickness of the coating layer 9 is in the range of 5 to 8 μm. Further, when the ratio p on the substrate 2 side is smaller than or equal to that on the outer surface side, the abrasion resistance of the

insert 1 deteriorates, and for example in cutting such as milling wet cutting, the boundary damage is particularly apt to occur, and the tool life of the tool is thus reduced.

[0035] It is to be noted that in the above configuration, when the ratio p at the time of performing a thin film X-ray diffraction analysis on the outer surface of the coating layer 9 is taken as p_s, p_s is 0.2 to 1, whereby the abrasion resistance of the coating layer 9 can be enhanced. p_s is preferably in the range of 0.45 to 0.9.

[0036] Further, in the above configuration, when the ratio p at the time of performing the thin film X-ray diffraction analysis in a state where area with a layer thickness within 1.5 μm from the substrate 2 side interface of the coating layer 9 is exposed is taken as p_b, p_b is 0.1 to 0.5, whereby adhesiveness of the coating layer 9 to the substrate 2 is improved. P_b is preferably in the range of 0.2 to 0.4.

[0037] It is further preferable that, when a ratio p_s/p_b of the ratio p_s to the ratio p_b is taken as r, r be 1.5 to 7. That is, when r is in this range, the abrasion of the coating layer 9 is proceeding slowly and the occurrence of micro flaking of the coating layer 9 or the like can be suppressed. Here, r is further preferably in the range of 2.5 to 4.5.

[0038] A honing 10 can further be provided in the corner cutting edge 5. While the shape of the honing 10 is preferably round R honing for suppressing flaking of the coating layer 9, it may be C honing (chamfer honing). It should be noted that as for a honing amount, a ratio R_r/R_f of R_r on the rake face 3 side to R_f on the flank face 4 side is preferably 1 to 1.5 in respect of the balance between the edge of the corner cutting edge 5 and fracture resistance performance. Further, it is preferable that the major cutting edge 6 side be larger and the minor cutting edge 7 side be smaller, the major cutting edge 6 being an end cutting edge and the minor cutting edge 7 being a peripheral cutting edge, for realizing a configuration suitable for a cutting environment of the cutting edge 8 at each position, to deliver the optimal cutting performance.

[0039] Moreover, it is preferable that the coating layer 9 be formed by sputtering because it renders a smooth surface and high adhesiveness resistance, as well as making the coating layer 9 resistant to occurrence of chipping and flaking without being self-destructed even when inner stress existing in the coating layer 9 is made smaller and the layer thickness is made larger.

[0040] Furthermore, while the coating layer 9 may be constituted of a simple composite of $Ti_{1-a}Al_aN$, for example, it may also be constituted of $Ti_{1-a-b}Al_aM_b(C_xN_{1-x})$ (where M is one or more kinds selected from Group 4, 5 and 6 elements of the periodic table except for Ti, rare-earth elements, and Si, and "$0 \leq a < 1$", "$0 < b \leq 1$" and "$0 \leq x \leq 1$" hold). It is to be noted that the composition of the coating layer 9 can be measured by energy dispersive X-ray spectrometry (EDS) or X-ray photoelectron spectroscopy (XPS).

[0041] As the substrate, in addition to cemented carbide or a cermet made up of a hard phase primarily composed of tungsten carbide or titanium carbonitride and a bonding phase primarily composed of an iron group metal such as cobalt or nickel, a hard material such as ultrahigh-pressure sintered compact obtained by sintering a hard phase made of ceramic primarily composed of silicon nitride or aluminum oxide, polycrystalline diamond or cubic boron nitride, and a bonding phase made of ceramic, iron group metal or the like under extreme pressure is preferably used.

[0042] While the cutting tool according to the present invention is usable on a variety of cutting conditions as the cutting tool, the tool particularly shows high abrasion resistance and fracture resistance on wet cutting conditions where cutting is performed using a cutting oil especially at the time of performing milling including end milling and drilling.

(Manufacturing Method)

[0043] Next described is an example of manufacturing methods concerning the cutting tool according to the aforementioned first embodiment.

[0044] First, a substrate in the shape of the tool is produced using a known method. Next, a coating layer is formed on the surface of the substrate. As the method for forming the coating layer, physical vapor deposition (PVD) such as ion plating or sputtering can be preferably adapted.

[0045] To describe an example of the coating methods in detail, in the case of producing the coating layer by ion plating, a metal target respectively independently containing metallic titanium (Ti), metallic aluminum (Al), and metallic M (where M is one or more kinds selected from Group 4, 5 and 6 elements of the periodic table except for Ti, rare-earth elements and Si), or an alloy target in combination of these is adopted.

[0046] As coating conditions, conditions can be preferably adopted where a metal source is evaporated and ionized by arc discharge, grow discharge or the like with use of the target, and is simultaneously reacted with a nitrogen (N_2) gas as a nitrogen source and a methane (CH_4)/acetylene (C_2H_2) gas as a carbon source. At this time, using a mixed gas of a nitride (N_2) gas and an argon (Ar) gas with flow rates of nitrogen to the argon gas in a ratio of 1:9 to 4:6, a coating layer is formed by ion plating or sputtering at a film formation temperature of 450 to 550°C with a sputtering power of 6 to 9 kW or a bias voltage of 30 to 200 V. According to the present invention, the layer coated by sputtering is preferably used since it is possible to form a uniform organization without generation of an abnormal section such as a droplet that is generated at the time of film formation by arc ion plating. Further, with low internal stress, even when the layer thickness is made larger, deterioration in fracture resistance due to accumulation of the internal stress tends not to occur. Therefore, thick layer can be formed and brittle flaking during processing can be suppressed so as to exert

the effect of improving the abrasion resistance by the surface coating.

[0047] According to the present invention, controlling a revolution speed of the sample during film formation to a higher speed in a latter period of the film formation than in a former period of the film formation can achieve the foregoing configuration of the coating layer.

(Second Embodiment)

[0048] A second embodiment of the cutting tool according to the present invention is described based upon an example of throwaway drills as a case in point. FIG. 6 is a schematic side view showing a drill according to the present embodiment. FIG. 7 is a schematic front view of the drill of FIG. 6 seen from its insert. FIG. 8 is a pattern view for explaining arrangements of an outer cutting edge and an inner cutting edge at the time of cutting with the drill of FIG. 6. It should be noted that in FIG. 8, an insert indicated by a broken line shows a position after revolution of the insert indicated by a solid line by 180 degrees.

[0049] As shown in FIGS. 6 to 8, a drill 21 according to the present embodiment is mounted separately with later-described two throwaway inserts (hereinafter simply abbreviated as inserts) 23 at the insert section of a tool body 22 with a rotating axis O at the center. One insert 23a is mounted at the insert section of the tool body 22 with a screw 24 such that an inner cutting edge 25 protrudes, and the other insert 23b is mounted with a screw 24 radially outside the insert 23a at the insert of the tool body 22 from the outer peripheral direction of the tool body 22 to the insert section of the tool body 22 such that the outer cutting edge 26 protrudes. That is, the insert 23a with the inner cutting edge 25 protruding from the tool body 22 is provided radially inside the insert 23b with the outer cutting edge 26 protruding from the tool body 22.

[0050] Here, the tool body 22 is formed in a substantially cylindrical shape, and has a revolution axis (line O in FIGS. 6 to 8) of the drill 21 and a shank section 28 on the rear end side for fixing itself to a tool machine, while being spirally formed with a chip discharge groove 29 on the insert side from the shank section 28 for discharging chips from the insert to the rear end of the tool body 22. Further, insert pockets 30 (30a, 30b) for fixing of the inserts 23 are provided at two positions in the insert section of the tool body 22, where an inner-side insert pocket 30a is opened to the axially insert side of the tool body 22 and mounted with the insert 23a, and an outer-side insert pocket 30b is opened from the axially insert side of the tool body 22 to the outer cutting edge and mounted with the insert 23b.

[0051] The drill 21 then cuts with the inner cutting edge 25 the inner peripheral side of the hole bottom face of a material to be cut (not shown) and cuts with the outer cutting edge 26 the outside and the outer periphery of the hole bottom face of the material to be cut (not shown), and as shown in FIGS. 7 and 8, the inner cutting edge 25 and the outer cutting edge 26 are arranged such that revolution paths of the inner cutting edge 25 and the outer cutting edge 26 cross each other and the cutting edges totally coat the drill 21 from the insert to the periphery thereof.

[0052] The insert 23 mounted in the drill 21 will be described in detail. FIG. 9 is a plan view showing the insert of the present embodiment. FIG. 10 is (a) a side view of the insert of FIG. 9 seen from the arrow A side, and (b) a side view of the same seen from the arrow B side. FIG. 11 is (a) an expanded view showing a cross section of the insert of FIG. 9 along line I-I and (b) an expanded view showing a cross section of the same along line II-II.

[0053] The insert 23 according to the embodiments shown in FIGS. 9 to 11 is formed in the shape of a substantially polygonal plate as seen from the above, and is formed with a through hole 34 at the center section of an upper face 31. Further, as shown in FIG. 11, a coating layer 36 is formed to cover the surface of a substrate 35 in the insert 23, and on a cross ridge line section 41 of the upper surface 31 and a side face 32 of the insert 23, the inner cutting edge 25 and the outer cutting edge 26 are formed adjacently to each other.

[0054] Here, according to the present embodiment, the coating layer 36 made of nitride or carbonitride containing Ti and Al and having a thickness of 3 to 15 μm on the cross ridge line section 41 is coated, and as shown in FIG. 11, the coating layer 36 is formed of a lower layer 38 and an upper layer 39. When a ratio I(400)/I(311) of a diffraction intensity I(400) of a plane (400) to a diffraction intensity 1(311) of a plane (311) concerning a micro X-ray diffraction peak of Cu-Karays of the coating layer 36 on a polished face formed by polishing the coating layer 36 obliquely to the thickness direction is taken as P, it is configured that P_1 measured on an unpolished face of the upper layer 39 is 0.1 to 0.5, P_3 measured in a portion where an interface of the lower layer 38 and the upper layer 39 on the polished face is exposed is smaller than P_2 measured on the polished face of the upper layer 39, and P_2 is smaller than P_1.

[0055] It is thereby possible to give the insert 23 having high abrasion resistance and high fracture resistance without flaking of the coating layer 36 in cutting, thus having a long tool life. In particular, even when the layer thickness on the cutting edge (inner cutting edge 25, outer cutting edge 26) on the coating layer 36 is made as large as 3 to 15 μm, the occurrence of cracking at the time of coating as the inner stress increases in the coating layer 36 on the cutting edge (inner cutting edge 25, outer cutting edge 26) and the occurrence of chipping of the cutting edge at the early stage of cutting due to a defect remaining inside the coating layer 36 are lowered. The thickness of the coating layer 36 is preferably in the range of 4 to 12 μm, and particularly preferably in the range of 4 to 8 μm.

[0056] It is to be noted that the present embodiment also has a configuration where, as for p, "$p_s > p_b$" holds, and p

is larger on the outer surface side than on the substrate side.

[0057] Here, a total thickness T_e of the coating layer 36 on the cutting edge (inner cutting edge 25, outer cutting edge 26) is 3 to 15 μm, and a ratio (T_e/T_f) to a thickness T_f of the coating layer 36 at a center position in the height direction (direction vertical to the cutting edge (inner cutting edge 25, outer cutting edge 26)) of the insert 23 as the center of the flank face (side surface 32) is 1.2 to 3.8, whereby it is possible to enhance the abrasion resistance of the cutting edge without impairing the fracture resistance thereof.

[0058] At this time, in the respect of allowing further control on flaking of the coating layer 36 on the cutting edge (inner cutting edge 25, outer cutting edge 26), it is preferable that, when a ratio (t_e/T_e) of a thickness t_e of the lower layer 38 to the total thickness T_e of the coating layer 36 on the cutting edge (inner cutting edge 25, outer cutting edge 26) is taken as A, the ratio A be 0.2 to 0.6, and when a ratio (t_f/T_f) of a thickness t_f of the lower layer 38 to the total thickness T_f of the coating layer 36 at a center position of the flank face (side surface 32) in the height direction of the insert 23 is taken as a, a ratio (A/a) of the ratio A to the ratio a be 0.4 to 0.9.

[0059] Further, it is preferable that the coating layer 36 be formed by physical vapor deposition (PVD), and it is more preferable that the lower layer 38 be formed by sputtering and the upper layer 39 be formed by arc ion plating in the respect of controlling the orientation of each layer, to obtain the hardness and adhesiveness of the coating layer 36. Moreover, in the case of the coating layer 36 with a later-mentioned composition, even when the coating layer 36 is formed to have large thickness, self-destruction of the coating layer 36 does not occur, and hence it is possible to suppress the occurrence of chipping and self-destruction of the coating layer 36.

[0060] While the composition of the coating layer 36 may be formed of simple $Ti_{1-a}Al_aN$, for example, it may also be formed of $Ti_{1-a-b}Al_aM_b(C_xN_{1-x})$ (where M is one or more kinds selected from Group 4, 5 and 6 elements of the periodic table except for Ti, rare-earth elements and Si, and "$0 \leq a < 1$", "$0 < b \leq 1$" and "$0 \leq x \leq 1$" hold). Especially, when it is formed of $Ti_{1-a-b-c}Al_aM_bW_c(C_yN_{1-y})$ (where M is one or more kinds selected from Group 4, 5 and 6 elements of the periodic table except for Ti and W, rare-earth elements and Si, and "$0.4 \leq a \leq 0.65$", "$0 \leq b \leq 0.5$", "$0.01 \leq c \leq 0.3$" and "$0 \leq y \leq 0.8$ hold), the coating layer 36 can be formed to have large thickness. It is to be noted that the composition of the coating layer 36 can be measured by energy dispersive X-ray spectrometry (EDS) or X-ray photoelectron spectroscopy (XPS).

[0061] Further, as shown in FIG. 11(a), while the inner cutting edge 25 is formed on the cross ridge line section 41 of the upper face 31 (inner-cutting-edge rake face 43) and the side face 32 (inner-cutting-edge flank face 44) of the insert 23, as shown in FIG. 11(a), an inner-cutting-edge land 42 of 0.05 to 0.15 mm and the inner-cutting-edge rake face 43 inclined downward with an inner-cutting-edge rake angle α_1 (angle formed by a virtual extended line L_2 of the inner-cutting-edge rake face 43 and line L_3 parallel to the lower surface 40) of 5 to 25° are formed sequentially from the inner cutting edge 25. Moreover, the inner-blade flank face 44 is formed on the side face 32 of the inner cutting edge 25 with an inner-cutting-edge flank angle β_1. In addition, a line vertical to the lower face (seated face) is denoted as L_1 in FIG. 11.

[0062] On the other hand, as shown in FIG. 11(b), the outer cutting edge 26 is formed on the cross ridge line section 41 of the upper face 31 (outer cutting edge rake face 49) and the side face 32 (outer-cutting-edge flank face 50) formed with an outer-cutting-edge flank angle β_2, and as shown in FIG. 9, the outer cutting edge 26 has on its one end side a protrusion 46 protruding outward from the insert 23 as seen from the above. As shown in FIG. 11(b), an outer-cutting-edge land 47 of 0.05 to 0.15 mm, an outer-cutting-edge breaker groove 48 with a width of 1.2 to 2 mm and a depth of 0.03 to 0.15 mm and an outer-cutting-edge land section 45 are formed in succession sequentially from the outer cutting edge 26. Further, an outer-cutting-edge flank face 50 is formed on the side face 32 of the outer cutting edge 26.

[0063] The outer-cutting-edge breaker groove 48 is made up of the outer-cutting-edge rake face 49 inclined downward with a rake angle α_2 (angle formed by a virtual extended line L_4 of the outer-cutting-edge rake face 49 and the line L_3 parallel to the lower surface 40) of 5 to 25°, and an outer-cutting-edge rising face 51 rising from the outer-cutting-edge rake face 49 toward the center side (through hole 34 side) of the insert 23 with a rising angle γ (angle formed by a virtual extended line L_5 of the outer-cutting-edge rising face 51 and the line L_3 parallel to the lower surface 40) of 20 to 45°.

[0064] It should be noted that for the substrate 35 constituting the insert 23, a similar material to that in the first embodiment can be preferably used.

(Manufacturing method)

[0065] As the method for forming the coating layer 36 on the substrate 35 after sintering, physical vapor deposition (PVD) such as ion plating or sputtering can be preferably adapted. Particularly, as an example of preferred coating methods according to the present invention, there can be cited a method for forming the coating layer 36 with use of a film formation apparatus 60 including both a magnetron sputtering cathode and arc ion plating cathode as shown in a pattern view of FIG. 13. That is, a method of forming the lower layer 38 by magnetron sputtering and forming the upper layer 39 by arc ion plating is preferably used.

[0066] In other words, the film formation apparatus 60 of FIG. 13 includes a sputtering section 68 that introduces a gas of N_2, Ar or the like from a gas inlet 62 into a vacuum chamber 61, and has a cathode electrode 67 and an anode

electrode 64, and the lower layer 38 is formed on the surface of the substrate 35 by sputtering between the electrodes.

[0067] After completing formation of the lower layer 38, the film formation apparatus 60 stops the arc discharge between a cathode electrode 63 and the anode electrode 64, applies high pressure between the cathode electrode 63 and the anode electrode 64 to generate plasma, evaporates desired metal or ceramic from the target 65 with this plasma, while ionizing it so as to come into a high energy state, and continues the film formation by an arc ion plating section 66 that makes this ionized metal adhere to the surface of a sample (substrate 35), so that the upper layer 39 is formed on the surface of the lower layer 38.

[0068] Further, according to FIG. 13, a heater 69 for heating the substrate 35, a gas outlet 70 for discharging a gas out of the system, and a bias power supply 71 for applying a bias voltage to the substrate 35 are arranged. A metal source is evaporated and ionized by arc discharge, grow discharge or the like with use of the target 65, and is simultaneously reacted with a nitrogen (N_2) gas as a nitrogen source and a methane (CH_4)/acetylene (C_2H_2) gas as a carbon source, to deposit the coating layer 36 on the surface of the substrate 35.

[0069] Specifically, a pulse power of 3 to 7 kW is applied to a magnetron sputtering cathode at a film formation temperature of 500 to 700°C. At that time, a repeated frequency is set to 20 to 100 kHz, and a duty cycle is set to 5 to 80%. As a bias voltage, a pulse DC voltage of 30 to 150 V, 50 to 350 kHz is applied and a nitrogen gas of 0.3 to 0.8 Pa is passed, to bring the state into a discharging state, thereby forming the lower layer 38.

[0070] Next, the ark discharge, the glow discharge or the like is applied onto the arc ion plating cathode with a bias voltage of 30 to 200 V at a film formation temperature of 400 to 600°C to evaporate and ionize the metal source, and simultaneously, the nitrogen (N_2) gas as the nitrogen source and the methane (CH_4)/acetylene (C_2H_2) gas as the carbon source are passed at a gas pressure of 2 to 5 Pa so as to be reacted, thereby forming the upper layer 39 on the surface of the lower layer 38.

[0071] Moreover, according to FIG. 13, a configuration is formed where the substrate 35 is placed in each of a plurality of sample supporting sections 74 provided in a sample supporting jig 73 mounted on a table 72 such that the rake face is opposed to the target 65, and a plurality of towers 76 are arranged (eight sets of sample supporting jigs 73 and two sets of towers 76 are shown in FIG. 13). In addition, it is taken into consideration that the sample supporting jig 73, the tower 76 and the table 72 are separately revolved and each sample is sequentially opposed to the target 65 so as to make the thickness of the coating layer uniform. In the present invention, the revolution speed in forming the upper layer 39 is made higher than the revolution speed in forming the lower layer 38 in the ratio of 1.1 to 3.0, thereby allowing control on the oriented states of the lower layer 38 and the upper layer 39.

[0072] It should be noted that the target may include a metal target independently containing metallic titanium (Ti), metallic aluminum (Al), metallic W, metallic Si, metallic M (where M is one or more kinds selected from Group 4, 5 and 6 elements of the periodic table except for Ti and W, and rare-earth elements), an alloy target in combination of these, or a mixed target made of a powder or a sintered object of a compound of these carbide, nitride and boride.

(Third Embodiment)

[0073] A third embodiment of the cutting tool according to the present invention is described based upon an example of throwaway drills as a case in point. Basic configurations of the drill according to the present invention are the same as those of the drill and the insert shown in the second embodiment described above.

[0074] Here, according to the present embodiment, as shown in FIG. 12, a coating layer 52 made of nitride or carbonitride containing Ti and Al and having a thickness of 3 to 10 μm on a cutting edge is coated, and when a ratio I(220)/(I(111) + I(200) + I(220) + 1(222) + I(400)) as to respective diffraction intensities I(111), I(200), I(220), I(222) and I(400) of planes (111), (200), (220), (222) and (400) concerning a micro X-ray diffraction peak of Cu-Kα rays of the coating layer 52 is taken as q and when a value q on a rake face (upper face 31 of FIGS. 9, 10), a value q on the flank face (side face 32 of FIG. 9, 10) and the value q on the cutting edge (inner cutting edge 25, outer cutting edge 26 of FIG. 12) are respectively taken as q_r, q_f and q_e, "$q_e > q_r$" and "$q_e > q_f$" hold.

[0075] It is thereby possible to give an insert 53 having high abrasion resistance and high fracture resistance without flaking of the coating layer 52 in cutting, thus having a long tool life. Especially, even when the thickness of the coating layer 52 on the cutting edge (inner cutting edge 25, outer cutting edge 26) is made as large as 3 to 10 μm, the occurrence of cracking at the time of film formation as the inner stress increases in the coating layer 52 on the cutting edge (inner cutting edge 25, outer cutting edge 26) and the occurrence of chipping of the cutting edge (inner cutting edge 25, outer cutting edge 26) at the early stage of cutting due to a defect remaining inside the coating layer 52 are prevented.

[0076] It is preferable here that "$q_e > q_r > q_f$" hold for improvement in adhesiveness resistance at the time of cutting.

[0077] Further, for allowing an increased thickness without occurrence of chipping or flaking due to impact at the time of cutting, to exert high abrasion resistance, it is preferable that, when a ratio I(400)/(I(111) + I(200) + I(220) + I(222) + I(400)) as to the respective diffraction intensities I(111), I(200), I(220), I(222) and I(400) of the planes (111), (200), (220), (222) and (400) of the coating layer 52 is taken as Q and when a value Q on the rake face (upper face 31 of FIGS. 9, 10), a value Q on the flank face (the upper face 32 of FIGS. 9, 10) and a value Q on the cutting edge (inner cutting edge

25, outer cutting edge 26 of FIG. 12) are respectively Q_r, Q_f and Q_e, "$Q_r > Q_e > Q_f$" hold.

[0078] Further, it is preferable that the coating layer 52 be formed by physical vapor deposition (PVD) as in the second embodiment, and it is more preferable that the layer be formed by arc ion plating in the respect of obtaining the hardness and adhesiveness.

[0079] According to the present embodiment, the film formation is performed while the orientation of the sample is revolved with the rake face, the cutting edge and the flank face each being revolved by 45° during the film formation. Performing the film formation on this condition can control the coating layer 36 in the direction of crystal growth. Further, since variations in thickness of the whole circumstance of the cutting edge of each sample can be made smaller, even when the whole thickness becomes larger, the sample is resistant to partial formation of a portion subject to chipping. Other processings are similar to those in the second embodiment.

Example 1

[0080] Using a tungsten carbide (WC) powder with an average particle size of 0.8 μm as a principal ingredient, a metallic cobalt (Co) powder with an average particle size of 1.2 μm, a vanadium carbide (VC) powder with an average particle size of 1.0 μm, and a chrome carbide (Cr_3C_2) powder with an average particle size of 1.0 μm were added and mixed at the rate of 10% by mass, 0.2 % by mass and 0.6 % by mass, to be molded into the shape of a cutting tool for cutting edge replaceable milling (BDMT11T308ER-JT) by press molding, which was then subjected to debinding and sintering at 1450°C in vacuum of 0.01 Pa for one hour, to produce cemented carbide. Further, the surface of the rake face of each sample was polished by blasting, blushing or the like, and the cutting edge was formed with honing. Moreover, the produced cemented carbide was subjected to blushing, and then honing, so as to set a honing amount to R_r = 0.03 mm and R_f = 0.02 mm. On the substrate as thus produced, a coating layer with a TiAlN composition was formed by sputtering at a coating temperature of 500°C on conditions shown in Table 1. It is to be noted that a revolution speed of each sample shown in Table 1 is the number of revolutions per minute in the way of counting as one time a full circle of the tower 16 holding the sample 15 in the pattern view of the film formation apparatus as seen from the above shown in FIG. 5. It should be noted that in FIG. 5, numeral 17 denotes a target, and a numeral 18 denotes a sample stage. Further, the thickness of the coating layer was measured at the center position of the flank face.

Table 1

Sample No.	Film forming conditions				Coating layer			
	Bias voltage (V)	Gas pressure (Pa)	Vapor deposition time (min.)	Revolution speed (rpm/min.)	Layer thickness (μm)	P_s	P_b	P_s/P_b
I - 1	100	Former 2.5 Latter 4	45 45	2.5 5	8.5	0.95	0.20	4.75
I - 2	100	4	55	2 6	4	0.31	0.23	1.35
I - 3	Initial 80 Final 120	Initial 3 Final 4	70	3.5 8	6.0	0.45	0.17	2.65
I - 4	Initial 80 Final 100	3.5	80	3 7.5	8	0.64	0.21	3.05
I - 5	120	Former 3 Latter 4.5	40 20	3.5 7.5	5.5	0.70	0.27	2.59
* I - 6	95	4	40	4	7.7	0.21	0.21	1.00
* I - 7	90	4	15 15	4 5	2.5	0.30	0.23	1.30
* I - 8	100	3	110 80	5.5 2	9.5	1.00	0.22	4.55
* I - 9	150	4	65	6	5.1	0.29	0.29	1.00
* shows a sample outside the scope of the present invention.								

[0081] Each of the obtained samples (I-1 to I-9) was subjected to a thin film X-ray diffraction analysis, to measure a peak strength ratio p of I(400)/I(311). It is to be noted that measurement conditions were: an incident angle of 2.0°; Cu-Kα rays; a step angle of 0.02°; and the time of 2 seconds. Further, as for p_s, the surface of the coating layer was not polished and the X-rays were applied onto the surface as it was to perform a thin film X-ray diffraction measurement, and as for p_b, etching was performed until the layer thickness becomes within 1.5 μm (about 1 μm) and the X-rays were then applied onto the exposed face of the coating layer to perform the thin film X-ray diffraction measurement, and p_s and p_b were calculated from diffraction peaks. Moreover, each insert was fixed to a holder, to produce the end mill of FIG. 1, and a cutting test was conducted on the following conditions.

Cutting method: Milling
Material to be cut: SKD11
Cutting speed: 150 m/min
Feeding: 0.12 mm/tooth
Cutting: lateral cutting 10 mm, depth cutting 3 mm
Cutting state: Wet
Evaluation method: The cutting edge was observed at the time point when the cutting has been done for 15 minutes, while an abrasion amount (width) on the flank face was measured. It is to be noted that caution should be taken not to include an amount of honing having been done in the abrasion width.

Table 2

Sample No.	Cutting evaluation		
	Abrasion width (mm)	Boundary-damage life	State of cutting blade
I - 1	0.06	45min	Good
I - 2	0.12	54 min	Good
I - 3	0.03	> 90min	Good
I - 4	0.03	70 min	Good
I - 5	0.08	80 min (Stopped due to large nose abrasion)	Good
* I - 6	0.11	30 min	Peeled
* I - 7	0.32	35 min	Boundary damaged
* I - 8	Chipped 10 min later		Peeled
* I - 9	0.22	22 min	Micro peeled
* shows a sample outside the scope of the present invention.			

[0082] According to Tables 1, 2, in each of Samples No. 1-6 and I-9 with the revolution timing thereof made constant during the film formation period, p_s and p_b were the same, p_s/p_b was not larger than 1, and the tool life was short in the cutting test. Further, in Samples No. I-7 with the thickness of the coating layer being smaller than 3 μm, boundary damage occurred at the early stage, while in Samples No. I-8 with the thickness of the coating layer being larger than 9 μm, micro flaking of the coating layer occurred, and hence in both samples, abrasion developed to shorten the tool lives.

[0083] As opposed to this, Sample No. I-1 to I-5 where p_s/p_b is larger than 1, namely p_s is larger than p_b, had good cutting performance.

Example 2

[0084] Using a tungsten carbide (WC) powder with an average particle size of 1.5 μm as a principal ingredient, a metallic cobalt (Co) powder with an average particle size of 1.2 μm, a titanium carbide (TiC) powder with an average particle size of 1.5 μm, and a tantalum carbide (TaC) powder with an average particle size of 1.0 μm were added and mixed at the rate of 10 % by mass, 3 % by mass and 7 % by mass, to be molded into the shape of a cutting tool for a cutting edge replaceable boning drill (ZCMT06T204) by press molding, which was then subjected to debinding and sintering at 1450°C in vacuum of 0.01 Pa for one hour, to produce cemented carbide. Further, the rake face surface of each sample was polished by blasting, blushing or the like. Moreover, the produced cemented carbide was subjected to blushing for honing such that the honing amount R was "0.02 mm $\leq$ R $\leq$ 0.04 mm."

[0085] On the substrate as thus produced, coating layers with a variety of compositions were formed on the coating conditions shown in Table 1, using the film formation apparatus including both a magnetron sputtering cathode and an arc ion plating cathode. It is to be noted that the conditions for forming the lower layer were: sputtering; a film formation temperature of 500°C; a repeated frequency of 50 kHz; a duty cycle of 75%; passing of a nitrogen gas of 0.3 to 0.8 Pa; and conditions shown in Table 3.

[0086] Next, the conditions for forming the upper layer were: arc ion plating; a film formation temperature of 550°C; introduction of a nitrogen (N_2) gas of 3.8 Pa into a chamber; and conditions shown in Table 1, to form the upper layer for production of the insert.

[0087] The rake face and the flank face of each of the obtained samples (II-1 to II-9) were precisely cut vertically to the cutting edge for observing the cross sections thereof, to measure the thickness of the coating layer from scanning electron micrograph (SEM) photographs. It is to be noted that the thickness of the coating layer was the largest on the cutting edge. Further, the flank face was polished obliquely to the flank face with an angle of 1°, and the X-ray diffraction analysis was performed in predetermined positions on the unpolished face and the polished face. A collimator diameter of 0.3 mmϕ, an output of 45 kV, 110 mA, an incident angle of 2.0°, Cu-Kα rays, a step angle of 0.02°, and the time of 2 seconds were set. P_1, P_2 and P_3 were calculated from diffractions peaks obtained by the X-ray diffraction analysis.

[0088] This insert was then mounted in the tool body (throwaway drill holder S25-DRZ1734-06, manufactured by KYOCERA Corporation) of FIG. 6 to conduct the following cutting test, and cutting performance was evaluated.

Cutting method: Milling (drilling)
Material to be cut: ductile cast iron (FCD450)
Cutting speed: 140m/min
Feeding: 0.12 mm/tooth
Cutting: hole diameter 20 mm, hole depth 40 mm
Cutting state: Wet
Evaluation method: The cutting was performed with 400-hole processing set as an upper limit, and the number of processing until occurrence of chipping of the inner cutting edge (or outer cutting edge) was recorded. Further, as for the outer cutting edge, after processing of 150 holes, an abrasion amount on the flank face was measured and abrasion resistance was also compared.

[0089] Results are shown in Tables 3 and 4.

Table 3

sample No.	Film forming conditions (Lower layer)		Film forming conditions (Upper layer)			Cutting blade		Flank face		
	Pulse power (Kw)	Revolving speed RL (rpm/min.)	Bias voltage (V)	Revolving speed RU (rpm/min.)	RU/RL	Te (μm)	A (te/Te)	p_3	p_2	p_1
II - 1	5	3	80	4	1.1	7.5	0.41	0.14	0.20	0.25
II - 2	5	3	50	6	2.7	8	0.15	0.11	0.12	0.15
II - 3	3	3	35	4	1.3	7	0.33	0.11	0.22	0.41
II - 4	4.5	3.5	30	4	1.5	5	0.30	0.18	0.23	0.30
II - 5	6	6	50	6	2.0	12	0.53	0.10	0.15	0.34
* II - 6	5	5	40	3	0.6	4	0.10	0.59	0.26	0.19
* II - 7	4	6	100	4	0.7	5.5	0.35	0.48	0.14	0.07
* II - 8	3.5	2	25	7	3.5	6.5	0.29	0.17	0.17	0.16
* II - 9	4.5	2.5	50	4	1.0	13	0.20	0.40	0.38	0.38
* shows a sample outside the scope of the present invention.										

Table 4

Sample No.	p			Central position of flank face				Cutting evaluation		
	p_s	p_b	p_s/p_b	T_f (μm)	a (t_f/T_f)	T_e/T_f	A/a	Abrasion width (mm)	Boundary-damage life	State of cutting blade
II - 1	0.38	0.23	1.65	4.5	0.32	1.7	1.3	0.15	350 holes	Good
II - 2	0.81	0.17	4.76	7	0.30	1.1	0.5	0.18	320 holes	Good
II - 3	0.52	0.33	1.58	3	0.47	2.3	0.7	0.09	> 400 holes	Good
II - 4	0.44	0.16	2.75	3.5	0.41	1.4	0.7	0.11	395 holes	Good
II - 5	0.51	0.13	3.92	7	0.70	1.7	0.8	0.14	384 holes	Good
* II - 6	0.12	0.31	0.39	2	0.05	2.0	2.0	0.55	250 holes	Boundary damaged
* II - 7	1.02	0.82	1.24	4	0.56	1.4	0.6	0.32	182 holes	Peeled
* II - 8	0.31	0.33	0.94	7	0.20	0.9	1.5	0.64	227 holes	Peeled
* II - 9	0.65	0.62	1.05	10	0.32	1.3	0.6	Chipped with 122 holes		Chipped
* shows a sample outside the scope of the present invention.										

[0090] As apparent from the results of Tables 3 and 4, in Sample No. II-9 where the revolving speed of the sample in forming the lower layer is the same as the revolution speed in forming the upper layer, the value P_3 is larger than the value P_1 and the value P_2, and chipping occurred in the cutting edge. Further, in Sample No. II-8 produced in coating conditions where the bias voltage and the revolution speed were adjusted such that the value P_1, the value P_2 and the value P_3 were almost the same, chipping occurred. Moreover, in Samples No. II-6, II-7 where the revolving speed of the sample in forming the upper layer is lower than the revolution speed of the sample in forming the lower layer, the value P_1, the value P_2 and the value P_3 were "$P_3 < P_2 < P_1$", and the abrasion width was large and the boundary-damage life was also large.

[0091] As opposed to this, Samples No. II-1 to II-5 each formed with the revolution speed in forming the upper layer with respect to the revolution speed of the sample in forming the lower layer being at the ratio of 1.1 to 3.0, "$P_3 < P_2 < P_1$" held, and both the abrasion resistance and the fracture resistance were high.

Example 3

[0092] With regard to a substrate produced in a similar manner to in Example 2, the sample was placed inside the film formation apparatus in the state of FIG. 7, and a nitrogen (N_2) gas was introduced into the chamber by arc ion plating, to form a TiAlN coating layer with the thickness shown in Table 1 by PVD on a condition of a bias voltage of 35 V so as to produce an insert (III-1 to III-10). It is to be noted that as for Samples No. III-1 to III-5, the orientation of the sample was revolved with the rake face, the cutting edge and the flank face each being revolved by 45° with the sample supporting jig in the intermediate stage of the film formation.

[0093] The rake face and the flank face of each of the obtained samples were precisely cut vertically to the cutting edge for observing the cross section thereof, to measure the thickness of the coating layer from scanning electron micrograph (SEM) photographs. It is to be noted that the thickness of the coating layer was the largest on the cutting edge. Further, micro X-ray diffraction analysis was performed on the rake face, the cutting edge and the flank face. A collimator diameter was set to 0.3 mmϕ, and the flat center of each of the faces was measured. It is to be noted that a ray source of Cu-Kα rays, an output of 45 kV and 110 mA, an incident angle of 2.0°, Cu-Kα rays, a step angle of 0.02°, and the time of 2 seconds were set. q_e, q_r and q_f and Q_r, Q_e and Q_f were calculated from diffractions peaks obtained by the X-ray diffraction analysis.

Table 5

Sample No.	Layer thickness (μm)		q[1)]			Q[2)]			P		
	Rake face	Flank face	q_r	q_f	q_e	Q_r	Q_f	Q_e	p_s	p_b	p_s/p_b
III - 1	3.3	4.8	0.055	0.051	0.066	0.033	0.022	0.035	0.49	0.24	2.04
III - 2	5.2	5.7	0.064	0.056	0.075	0.033	0.025	0.026	0.58	0.23	2.52
III - 3	7.8	6.5	0.064	0.054	0.066	0.028	0.032	0.030	0.55	0.23	2.39
III - 4	4.3	4.3	0.051	0.027	0.062	0.032	0.027	0.028	0.62	0.16	3.88
III - 5	10.0	8.5	0.052	0.055	0.071	0.023	0.033	0.025	0.73	0.39	1.87
* III - 6	5.5	5.6	0.055	0.052	0.050	0.035	0.031	0.030	0.48	0.08	6.00
* III - 7	11.0	11.7	0.063	0.058	0.066	0.034	0.034	0.032	0.12	0.07	1.71
* III - 8	1.7	1.8	0.052	0.030	0.058	0.029	0.023	0.024	0.49	0.54	0.91
* III - 9	3.7	4.0	0.056	0.051	0.056	0.033	0.022	0.033	0.45	0.45	1.00
* III - 10	5.0	5.6	0.048	0.061	0.046	0.031	0.033	0.034	0.44	0.51	0.86
* shows a sample outside the scope of the present invention.											

[0094] This insert was then mounted in a tool body (throwaway drill holder S25-DRZ1734-06, manufactured by KYOCERA Corporation) of FIG. 1 to conduct the following cutting test, and cutting performance was evaluated.

Cutting method: Milling (drilling)
Material to be cut: Carbon steel (S45C)
Cutting speed: 150 m/min
Feeding: 0.25 mm/tooth
Cutting: hole diameter 20 mm, hole depth 20 mm
Cutting state: Wet
Evaluation method: The cutting was performed with 700-hole processing set as an upper limit, and the number of processing until occurrence of chipping of the inner cutting edge (or outer cutting edge) was recorded. Further, as for the outer cutting edge, after processing of 400 holes, an abrasion amount on the flank face was measured and abrasion resistance was also compared.

[0095] Results are shown in Table 6.

Table 6

Sample No.	Cutting characteristics		
	Edge section, state of appearance	Chipping life (inner blade)	Abrasion amount on flank face (outer blade)
III - 1	Good	>700 holes	0.043 mm
III - 2	Good	>700 holes	0.029 mm
III - 3	Good	>700 holes	0.041 mm
III - 4	Good	>700 holes	0.034 mm
III - 5	slightly adhering	680 holes	0.057 mm
* III - 6	slightly adhering	550 holes	0.093 mm
* III - 7	Peeled	116 holes	-
* III - 8	Significantly abraded	41 holes	-
* III - 9	chipped	600 holes	0.177 mm

(continued)

Sample No.	Cutting characteristics		
	Edge section, state of appearance	Chipping life (inner blade)	Abrasion amount on flank face (outer blade)
* III - 10	Peeled	145 holes	-
* shows a sample outside the scope of the present invention.			

[0096] As apparent from the results of Tables 5 and 6, in Sample No. III-8 with the thickness of the coating layer on the cutting edge being smaller than 3 μm, the abrasion amount of the insert was large. Further, in Sample No. III-7 with the thickness of the coating layer exceeding 10 μm, fracture resistance was poor. Moreover, in Sample No. III-6 where "$q_e < q_f$" holds, abrasion resistance was poor, and in sample No. III-9 where "$q_e = q_r$" holds, the inner cutting edge also becomes chipped at the early stage. Furthermore, in Sample No. III-10 where "$q_e < q_r$" and "$q_e < q_f$" hold, flaking of the coating layer occurred on the cutting edge at the time of visual inspection after completion of the film formation, and the cutting edge also becomes chipped at the early stage of the cutting.

[0097] As opposed to this, in each of Samples No. III-1 to III-5 where the thickness of the coating layer on the cutting edge was 3 to 10 μm and "$q_e > q_r$" and "$q_e > q_f$" hold according to the present invention, fracture resistance and abrasion resistance were high.

Example 4

[0098] Except for the use of the substrate and the coating layer with compositions described in Table 7, the coating layer was formed in a similar manner to in Example 3, to produce an insert, and a cutting test was conducted using each of materials to be cut in Table 8 on the following conditions, and evaluated in a similar manner to in Example 3 (IV-1 to IV-6). The results were shown in Table 8.

Cutting method: drilling

Cutting speed: 120 m/min

Feed: 0.1 mm/tooth

Cutting: Hole diameter 20 mm, Hole depth 40 mm

Cutting state: Wet

Evaluation method: The cutting was performed with 400-hole processing set as an upper limit, and the number of processing was recorded until occurrence of chipping of the inner cutting edge (or outer cutting edge). Further, as for the outer cutting edge, after processing of 200 holes, an abrasion amount on the flank face was measured and abrasion resistance was also compared.

Table 7

Sample No.	Blending composition (t by mass)				Interface roughness (μm)	Film forming conditions			
	wc	Co	Other additives			Bias voltage (V)	Gass pressure (pa)	vapor deposition time(min.)	Revolving speed (rpm/min.)
IV - 1	Remaining	10	TiC TaC	2.1 7.2	0.1	100	Former 2 Latter 4	45 45	2 5
IV - 2	Remaining	10	Cr_3C_2	0.6	0.05	100	4	55	2 5

(continued)

Sample No.	Blending composition (t by mass)				Interface roughness (μm)	Film forming conditions			
	wc	Co	Other additives			Bias voltage (V)	Gass pressure (pa)	vapor deposition time(min.)	Revolving speed (rpm/min.)
IV - 3	Remaining	7.3	TaC ZrC	0.7 0.6	0.05	Initial 80 Final 120	Initial 3 Final 4	70	3.5 7
* IV - 4	Remaining	10	Cr_3C_2	0.6	0.2	100	4	70	5
* IV - 5	Remaining	6	TiC TaC	2.8 6.7	0.1	90	4	10 10	4 5
* IV - 6	Remaining	6.2	TiC TaC ZrC	1.5 3.4 1.0	0.05	130	4	70	6 3
* shows a sample outside the scope of the present invention.									

Table 8

Sample No.	Coating layer					Material to be cut	Life	State of cutting blade
	Composition	Film thickness (μm)	p_a	p_b	p_a/p_b			
IV - 1	$(Ti_{0.45}A1_{0.49}W_{0.03}Si_{0.02}Nb_{0.01})$ N	4.8	0.41	0.24	1.71	SCM440H	> 400 holes	Good
IV - 2	$(Ti_{0.44}Al_{0.49}W_{0.02}Si_{0.03}Hf_{0.02})$ N	3.0	0.39	0.23	1.70	SUS304	> 400 holes	Good
IV - 3	$(Ti_{0.50}Al_{0.46}W_{0.02}Si_{0.01}Mo_{0.01})N$	5.5	0.54	0.21	2.57	FCD450	> 400 holes	Good
* IV - 4	$(Ti_{0.48}Al_{0.47}W_{0.02}Nb_{0.02}Si_{0.01})N$	6.5	0.45	0.45	1.00	SCH440H	228 holes	Significantly abraded, chipped
* IV - 5	$(Ti_{0.32}Al_{0.45}W_{0.05}Si_{0.06}Mo_{0.12})C_{0.5}N_{0.5}$	1.3	0.28	0.21	1.33	FCD450	68 holes	Stopped processing
* IV - 6	$(Ti_{0.43}Al_{0.42}W_{0.07}Si_{0.06}Mo_{0.02})N$	4.7	0.30	0.34	0.88	SUS304	251 holes	Significantly abraded
* shows a sample outside the scope of the present invention.								

[0099] According to Tables 7 and 8, in Samples No. IV-4, IV-6 where p_s/p_b is not larger than 1, the tool life was also short in the cutting test. Further, in Sample No. IV-5 where the thickness of the coating layer was shorter than 3 μm, the boundary damage occurred at the early stage and abrasion develops, to shorten the tool life. As opposed to this, in Samples No. IV-1 to IV-3 where p_s/p_b was larger than 1, namely p_s was larger than p_b, cutting performance was good.

BRIEF DESCRIPTION OF THE DRAWINGS

[0100]

FIG. 1 is a schematic perspective view showing an example of throwaway milling tools as a first embodiment of a cutting tool according to the present invention;
FIG. 2 shows an example of throwaway inserts to be mounted on the throwaway milling tool of FIG. 1, where (a) is a schematic perspective view and (b) is a plan view;
FIG. 3 is a schematic sectional view along ling a-a in FIG. 2(a);
FIG. 4 shows a thin film X-ray diffraction pattern concerning a coating layer of the throwaway insert of FIG. 3, where (a) is a thin film X-ray diffraction pattern at the time of applying X-rays from the outer surface of the coating layer, and (b) is a thin film X-ray diffraction pattern at the time of applying X-rays onto an exposed surface after removal of the upper portion of the coating layer such that its thickness is within 1.5 μm from the substrate.
FIG. 5 is a pattern view of a film formation apparatus, which forms a coating layer of the cutting tool in Example 1 (first embodiment) of the cutting tool according to the present invention, seen from the above for explaining an arrangement of the film formation apparatus;
FIG. 6 is a schematic side view showing a drill in accordance with a second embodiment of the cutting tool according to the present invention;
FIG. 7 is a schematic front view of the drill of FIG. 6 seen from its insert section;
FIG. 8 is a pattern view for explaining arrangements of an outer cutting edge and an inner cutting edge at the time of cutting with the drill of FIG. 6;
FIG. 9 is a plan view showing a throwaway insert (insert) to be mounted in the drill of FIG. 6;
FIG. 10 shows the insert of FIG. 9, where (a) is a side view seen from an arrow A side, and (b) is a side view seen from an arrow B side;
FIG. 11 shows the insert of FIG. 9, where (a) is an expanded view showing a cross section along line I-I, and (b) an expanded view showing a cross section along line II-II;
FIG. 12 shows the insert of FIG. 9 in the drill of the second embodiment in another embodiment (third embodiment), where (a) is an expanded view showing a cross section along the line I-I, and (b) is an expanded view showing a cross section along the line II-II; and
FIG. 13 is a pattern view of a film formation apparatus as an example of methods for forming a coating layer of the insert of FIGS. 11 and 12.

EXPLANATION OF REFERENCE NUMERALS

[0101]

A:	Throwaway milling tool (tool)
1	Throwaway insert (insert)
2	Substrate
3	Rake face
4	Flank face
5	Corner cutting edge
6	Major cutting edge
7	Minor cutting edge
8	Cutting edge
9	Coating layer
10	Honing
R_r	Honing amount R_r on rake face 3 side
R_f	Honing amount R_f on flank face 4 side
11	Holder
12	Insert pocket
13	Screw
14	Screw hole

15	Sample
16	Tower
17	Target
18	Sample stage
21	Drill
22	Tool body
23, 53	Throwaway insert (insert)
23a	One insert
23b	Another insert
24	Screw
25	Inner cutting edge
26	Outer cutting edge
28	Shank section
29	Chip discharge groove
30	Insert pocket
30a	Inner-side insert pocket
30b	Outer-side insert pocket
31	Upper face
32	Side face
34	Through hole
35	Substrate
36, 52	Coating layer
38	Lower layer
39	Upper layer
40	Lower face (seated face)
41	Cross ridge line section
42	Inner-cutting-edge land
43	Inner-cutting-edge rake face
44	Inner-cutting-edge flank face
45	Outer-cutting-edge land section
46	Protrusion
47	Outer-cutting-edge land
48	Outer-cutting-edge breaker groove
49	Outer-cutting-edge rake face
50	Outer-cutting-edge flank face
51	Outer-cutting-edge rising face
60	Film formation apparatus
61	Vacuum chamber
62	Gas inlet
63, 67	Cathode electrode
64	Anode electrode
65	Target
66	Arc ion plating section
68	Sputtering section
69	Heater
70	Gas outlet
71	Bias power supply
72	Table
73	Sample supporting jig
74	Sample supporting section
76	Tower
O	Drill rotating axis
L_1	Line vertical to lower surface (seated face)
L_2	Virtual extended line of inner-cutting-edge rake face
L_3	Line parallel to lower face (seated face)
L_4	Virtual extended line of outer-cutting-edge rake face
L_5	Virtual extended line of outer-cutting-edge rising face
α_1	Inner-cutting-edge rake angle

α_2 Outer-cutting-edge rake angle
β_1 Inner-cutting-edge flank angle
β_2 Outer-cutting-edge flank angle
γ Raising angle

Claims

1. A cutting tool, comprising:

a substrate (2);
a flank face (4);
a rake face (3); and
a coating layer (9) on the substrate (2), the coating layer having an outer surface and a substrate side, the coating layer being located at the flank face (4), wherein the coating layer consists of nitride or carbonitride containing Ti and Al and has a thickness of 3 to 9 μm at the flank face (4), wherein
a first intensity ratio I (400) / I (311) (p_s) of a diffraction intensity I(400) of a crystal plane (400) to a diffraction intensity I(311) of a crystal plane (311) measured by a thin film X-ray diffraction method using Cu-Kα rays of the coating layer (9) on the outer surface at the flank face is 0.2 - 1 and is higher than the first intensity ratio (p_b) of the coating layer (9) on the substrate side at the flank face.

2. The cutting tool according to claim 1, wherein
the first intensity ratio (p_b) of the coating layer (9) on an exposed surface at a thickness of 1.5 μm from an interface of the coating layer (9) with the substrate is 0.1 and 0.5.

3. The cutting tool according to claim 1 or 2, wherein
a ratio (p_s/p_b) of the first intensity ratio (p_s) of the coating layer (9) on an outer surface to the first intensity ratio (p_b) of the coating layer (9) on the exposed surface is 1.5 to 7.

4. The cutting tool according to any one of claims 1 to 3, wherein:

the coating layer consists of a lower layer (38) and an upper layer (39); wherein
a second intensity ratio I(400)/I(311) (P_1) of a diffraction intensity I(400) to a diffraction intensity I(311) of the coating layer (9) on the outer surface measured by an X-ray diffraction method using Cu-Kα is 0.1 to 0.5;
the second intensity ratio (P_2) of the coating layer (9) on a polished surface of the upper layer (39) is lower than the first intensity ratio (P_1) on the outer surface; and
the second intensity ratio (P_3) of the upper layer (39) at an interface between the upper layer (39) and the lower layer (38) is lower than the second intensity ratio (P_2) on the polished surface.

5. The cutting tool according to claim 4, further comprising a cutting edge, wherein:

a thickness (T_e) of the coating layer (9) on a cutting edge (8) is 3 to 15 μm; and
a ratio (T_e/T_f) of the thickness (T_e) of the coating layer (9) on the cutting edge (8) to a thickness (T_f) of coating layer (9) at a center position of the flank face (4) is 1.2 to 3.8.

6. The cutting tool according to claim 5, wherein:

a first thickness ratio ($A = t_e/T_e$) of a thickness (t_e) of the lower layer on the cutting edge (8) to the thickness (T_e) of the coating layer (9) on the cutting edge (8) is 0.2 to 0.6; and a ratio (A/a) of the first thickness ratio to a second thickness ratio (t_f/T_f) of a thickness (t_f) of the lower layer at the center position of the flank face to the thickness (T_f) of the coating layer at the center position of the flank face, is 0.4 to 0.9.

7. The cutting tool according to any one of claims 1 to 6, further comprising a rake face, wherein:

the coating layer on the cutting edge (8) has a thickness of 3 to 10 μm; and
a third intensity ratio (q_e) of I(220)/(I(111) + I(200) + I(220) + I(222) + I(400)measured by a micro X-ray diffraction method using the Cu-Kα rays of the coating layer on the cutting edge (8) is higher than the third intensity ratio (q_r) of the coating layer (9) on the rake face (3) and the third intensity ratio (q_f) of the coating layer (9) on the

flank face (4).

8. The cutting tool according to claim 7, wherein the third intensity ration (q_r) of the coating layer (9) on the rake face (3) is higher than the third intensity ratio (q_f) of the coating layer (9) on the flank face (4).

9. The cutting tool according to claim 7 or 8, wherein:

a fourth intensity ratio (Q_r) of I(400)/(I(111) + I(200) + I(220) + I(222) + I(400) of the coating layer (9) on the rake face is higher than the fourth intensity ratio (Q_e) of the coating layer (9) on the cutting edge; and
the fourth intensity ratio (Q_e) of the coating layer on the cutting edge (8) is higher than the fourth intensity ratio (Q_f) of the coating layer (9) on the flank face.

Patentansprüche

1. Ein Schneidwerkzeug, aufweisend:

ein Substrat (2),
eine Flankenfläche (4),
eine Spanfläche (3), und
eine Beschichtungsschicht (9) auf dem Substrat (2), wobei die Beschichtungsschicht eine Außenfläche und eine Substratseite hat, wobei sich die Beschichtungsschicht an der Flankenfläche (4) befindet, wobei die Beschichtungsschicht aus Nitrid oder Carbonitrid besteht, das Ti und Al enthält, und an der Flankenfläche (4) eine Dicke von 3 μm bis 9 μm hat, wobei
ein erstes Intensitätsverhältnis I(400)/I(311) (p_s) einer Beugungsintensität I(400) einer Kristallebene (400) zu einer Beugungsintensität I(311) einer Kristallebene (311), gemessen durch ein Dünnfilm-Röntgenbeugungsverfahren mittels Cu-Kα-Strahlen, der Beschichtungsschicht (9) auf der Außenfläche an der Flankenfläche 0,2 - 1 beträgt und größer als das erste Intensitätsverhältnis (p_b) der Beschichtungsschicht (9) auf der Substratseite an der Flankenfläche ist.

2. Das Schneidwerkzeug gemäß Anspruch 1, wobei
das erste Intensitätsverhältnis (p_b) der Beschichtungsschicht (9) auf einer freigelegten Fläche bei einer Dicke von 1,5 μm ausgehend von einer Grenzfläche der Beschichtungsschicht (9) mit dem Substrat 0,1 und 0,5 beträgt.

3. Das Schneidwerkzeug gemäß Anspruch 1 oder 2, wobei
ein Verhältnis (p_s/p_b) des ersten Intensitätsverhältnisses (p_s) der Beschichtungsschicht (9) auf einer Außenfläche zu dem ersten Intensitätsverhältnis (p_b) der Beschichtungsschicht (9) auf der freigelegten Fläche 1,5 bis 7 beträgt.

4. Das Schneidwerkzeug gemäß irgendeinem der Ansprüche 1 bis 3, wobei:

die Beschichtungsschicht aus einer unteren Schicht (38) und einer oberen Schicht (39) besteht, wobei
ein zweites Intensitätsverhältnis I(400)/I(311) (p_1) einer Beugungsintensität I(400) zu einer Beugungsintensität I(311) der Beschichtungsschicht (9) auf der Außenfläche, gemessen durch ein Röntgenbeugungsverfahren mittels Cu-Kα, 0,1 bis 0,5 beträgt,
das zweite Intensitätsverhältnis (P_2) der Beschichtungsschicht (9) auf einer polierten Oberfläche der oberen Schicht (39) kleiner als das erste Intensitätsverhältnis (P_1) auf der Außenfläche ist, und
das zweite Intensitätsverhältnis (P_3) der oberen Schicht (39) an einer Grenzfläche zwischen der oberen Schicht (39) und der unteren Schicht (38) kleiner als das zweite Intensitätsverhältnis (P_2) auf der polierten Oberfläche ist.

5. Das Schneidwerkzeug gemäß Anspruch 4, ferner aufweisend eine Schneidkante, wobei:

eine Dicke (T_e) der Beschichtungsschicht (9). an einer Schneidkante (8) 3 μm bis 15 μm beträgt, und
ein Verhältnis (T_e/T_f) der Dicke (T_e) der Beschichtungsschicht (9) an der Schneidkante (8) zu einer Dicke (T_f) der Beschichtungsschicht (9) in einer Mittenposition der Flankenfläche (4) 1,2 bis 3,8 beträgt.

6. Das Schneidwerkzeug gemäß Anspruch 5, wobei:

ein erstes Dickenverhältnis ($A = t_e/T_e$) einer Dicke (t_e) der unteren Schicht an der Schneidkante (8) zu der Dicke

(T_e) der Beschichtungsschicht (9) an der Schneidkante (8) 0,2 bis 0,6 beträgt, und ein Verhältnis (A/a) des ersten Dickenverhältnisses zu
einem zweiten Dickenverhältnis (t_f/T_f) einer Dicke (t_f) der unteren Schicht in der Mittenposition der Flankenfläche zu der Dicke (T_f) der Beschichtungsschicht in der Mittenposition der Flankenfläche 0,4 bis 0,9 beträgt.

7. Das Schneidwerkzeug gemäß irgendeinem der Ansprüche 1 bis 6, ferner aufweisend eine Spanfläche, wobei:

die Beschichtungsschicht an der Schneidkante (8) eine Dicke von 3 μm bis 10 μm hat, und
ein drittes Intensitätsverhältnis (q_e) von I(220)/ (I(111) + I(200) + I(220) + I(222) + I(400), gemessen durch ein Mikro-Röntgenbeugungsverfahren mittels der Cu-Kα-Strahlen, der Beschichtungsschicht an der Schneidkante (8) größer als das dritte Intensitätsverhältnis (q_r) der Beschichtungsschicht (9) auf der Spanfläche (3) und das dritte Intensitätsverhältnis (q_f) der Beschichtungsschicht (9) auf der Flankenfläche (4) ist.

8. Das Schneidwerkzeug gemäß Anspruch 7, wobei das dritte Intensitätsverhältnis (q_r) der Beschichtungsschicht (9) auf der Spanfläche (3) größer als das dritte Intensitätsverhältnis (q_f) der Beschichtungsschicht (9) auf der Flankenfläche (4) ist.

9. Das Schneidwerkzeug gemäß Anspruch 7 oder 8, wobei:

ein viertes Intensitätsverhältnis (Q_r) von I(400)/ (I(111) + I(200) + I(220) + I(222) + I(400) der Beschichtungsschicht (9) auf der Spanfläche größer als das vierte Intensitätsverhältnis (Q_e) der Beschichtungsschicht (9) an der Schneidkante ist, und
das vierte Intensitätsverhältnis (Q_e) der Beschichtungsschicht an der Schneidkante (8) größer als das vierte Intensitätsverhältnis (Q_f) der Beschichtungsschicht (9) auf der Flankenfläche ist.

Revendications

1. Un outil de coupe, comportant :

un substrat (2),
une face de flanc (4),
une face de coupe (3), et
une couche de revêtement (9) sur le substrat (2), la couche de revêtement ayant une surface extérieure et un côté de substrat, la couche de revêtement étant située à la face de flanc (4), dans lequel la couche de revêtement est constituée de nitrure ou nitrure de carbone contenant Ti et Al, et a une épaisseur de 3 μm à 9 μm à la face de flanc (4), dans lequel
un premier rapport d'intensité I(400)/I(311) (p_s) d'une intensité de diffraction I(400) d'un plan cristallin (400) à une intensité de diffraction I(311) d'un plan cristallin (311), mesuré par un procédé de diffraction aux rayons X de couche mince moyennant des rayons Cu-Kα, de la couche de revêtement (9) sur la surface extérieure à la face de flanc est 0,2 - 1, et est supérieur au premier rapport d'intensité (p_b) de la couche de revêtement (9) du côté de substrat à la face de flanc.

2. L'outil de coupe selon la revendication 1, dans lequel
le premier rapport d'intensité (p_b) de la couche de revêtement (9) sur une surface exposée à une épaisseur de 1,5 μm à partir d'une interface de la couche de revêtement (9) avec le substrat est 0,1 et 0,5.

3. L'outil de coupe selon la revendication 1 ou 2, dans lequel
un rapport (p_s/p_b) du premier rapport d'intensité (p_s) de la couche de revêtement (9) sur une surface extérieure au premier rapport d'intensité (p_b) de la couche de revêtement (9) sur la surface exposée est 1,5 à 7.

4. L'outil de coupe selon l'une quelconque des revendications 1 à 3, dans lequel :

la couche de revêtement est constituée d'une couche inférieure (38) et d'une couche supérieure (39),
un deuxième rapport d'intensité I(400)/I(311) (P_1) d'une intensité de diffraction I(400) à une intensité de diffraction I(311) de la couche de revêtement (9) sur la surface extérieure, mesuré par un procédé de diffraction aux rayons X moyennant Cu-Kα étant 0,1 à 0,5,
le deuxième rapport d'intensité (P_2) de la couche de revêtement (9) sur une surface polie de la couche supérieure

(39) étant inférieur au premier rapport d'intensité (P_1) sur la surface extérieure, et
le deuxième rapport d'intensité (P_3) de la couche supérieure (39) au niveau d'une interface entre la couche supérieure (39) et la couche inférieure (38) étant inférieur au deuxième rapport d'intensité (P_2) sur la surface polie.

5. L'outil de coupe selon la revendication 4, comportant en outre un bord de coupe, dans lequel :

une épaisseur (T_e) de la couche de revêtement (9) sur un bord de coupe (8) est 3 μm à 15 μm, et
un rapport (T_e/T_f) de l'épaisseur (T_e) de la couche de revêtement (9) sur le bord de coupe (8) à une épaisseur (T_f) de la couche de revêtement (9) à une position de centre de la face de flanc (4) est 1,2 à 3,8.

6. L'outil de coupe selon la revendication 5, dans lequel :

un premier rapport d'épaisseur ($A = t_e/T_e$) d'une épaisseur (t_e) de la couche inférieure sur le bord de coupe (8) à l'épaisseur (T_e) de la couche de revêtement (9) sur le bord de coupe (8) est 0,2 à 0,6 ; et un rapport (A/a) du premier rapport d'épaisseur à
un deuxième rapport d'épaisseur (t_f/T_f) d'une épaisseur (t_f) de la couche inférieure à la position centrale de la face de flanc à l'épaisseur (T_f) de la couche de revêtement à la position de centre de la face de flanc est 0,4 à 0,9.

7. L'outil de coupe selon l'une quelconque des revendications 1 à 6, comportant en outre une face de coupe, dans lequel :

la couche de revêtement sur le bord de coupe (8) a une épaisseur de 3 μm à 10 μm, et
un troisième rapport d'intensité (q_e) de I(220)/(I(111) + 1(200) + I(220) + I(222) + I(400), mesuré par un procédé de micro-diffraction aux rayons X moyennant les rayons Cu-Kα de la couche de revêtement sur le bord de coupe (8) est supérieur au troisième rapport d'intensité (q_r) de la couche de revêtement (9) sur la face de coupe (3) et le troisième rapport d'intensité (q_f) de la couche de revêtement (9) sur la face de flanc (4).

8. L'outil de coupe selon la revendication 7, dans lequel le troisième rapport d'intensité (q_r) de la couche de revêtement (9) sur la face de coupe (3) est supérieur au troisième rapport d'intensité (q_f) de la couche de revêtement (9) sur la face de flanc (4).

9. L'outil de coupe selon la revendication 7 ou 8, dans lequel :

un quatrième rapport d'intensité (Q_r) de I(400)/(I(111) + I(200) +I(220) +I(222) + 1(400) de la couche de revêtement (9) sur la face de coupe est supérieur au quatrième rapport d'intensité (Q_e) de la couche de revêtement (9) sur le bord de coupe, et
le quatrième rapport d'intensité (Q_e) de la couche de revêtement sur le bord de coupe (8) est supérieur au quatrième rapport d'intensité (Q_f) de la couche de revêtement (9) sur la face de flanc.

Fig. 1

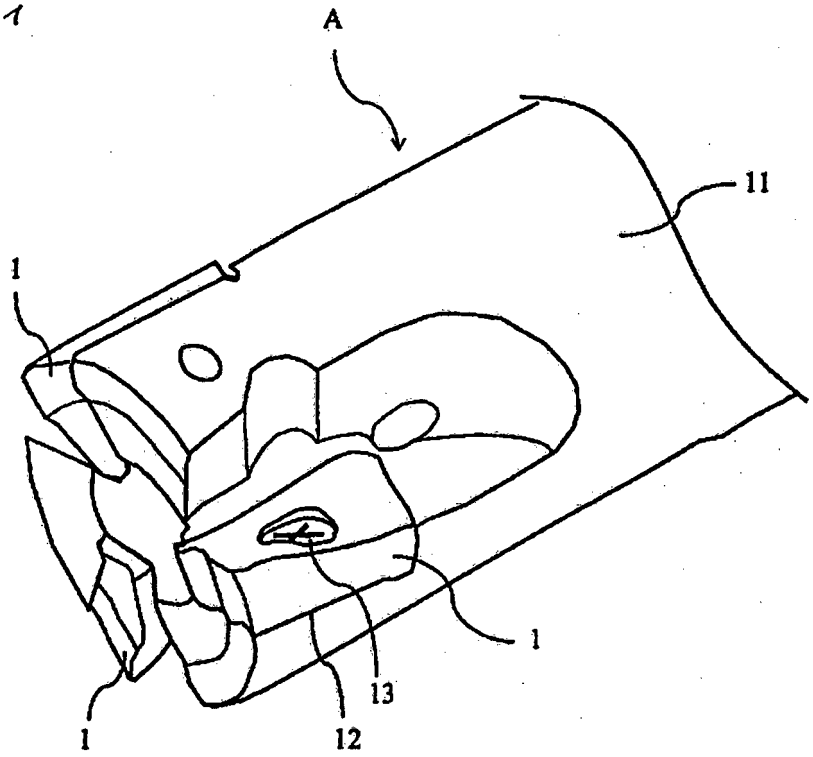
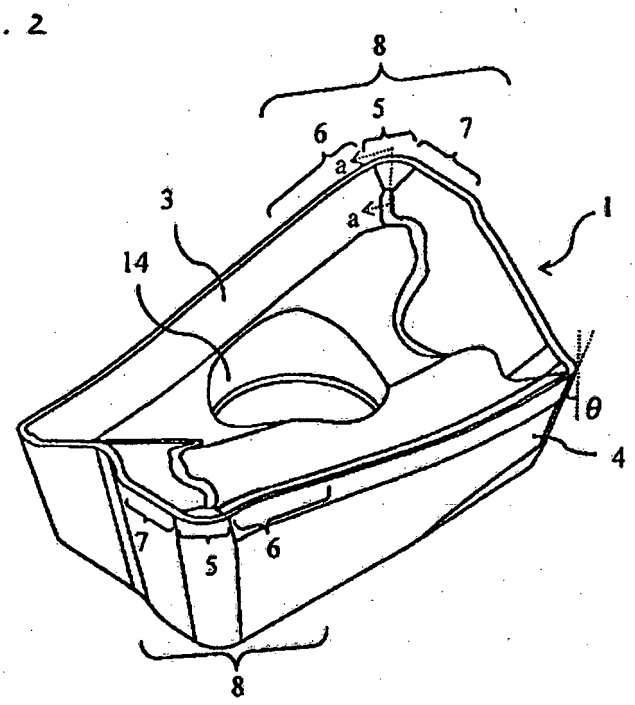
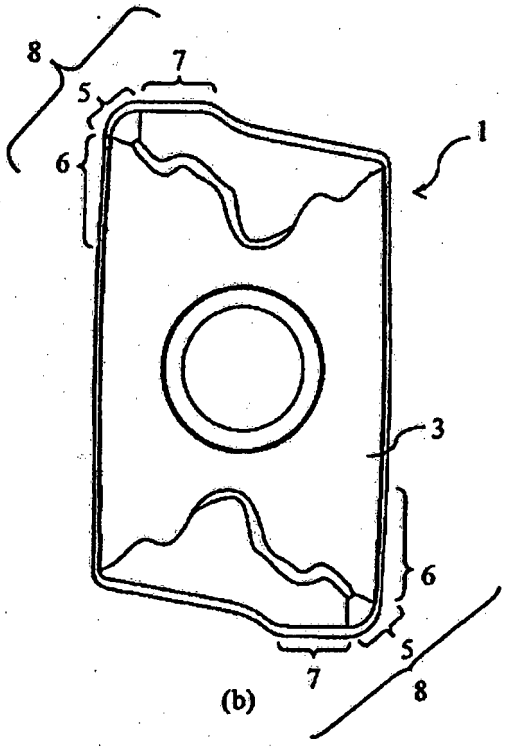


Fig. 2



(a)



(b)

Fig. 3

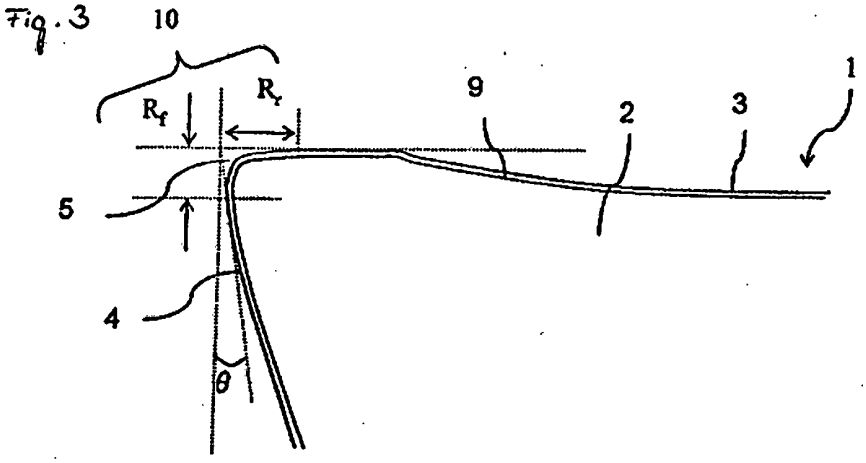

10
R_f
R_r
9
2
3
1
5
4
θ

Fig.4

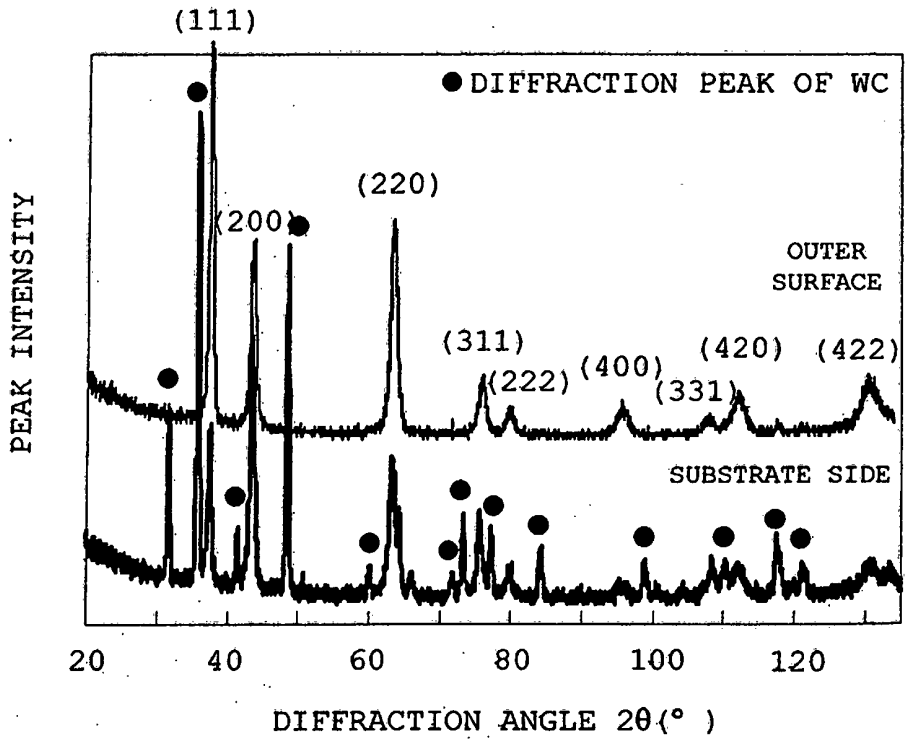

(111)
● DIFFRACTION PEAK OF WC
(220)
(200)
OUTER SURFACE
(311)
(222)
(400)
(420)
(422)
(331)
SUBSTRATE SIDE
PEAK INTENSITY
20
40
60
80
100
120
DIFFRACTION ANGLE 2θ(°)

Fig. 5

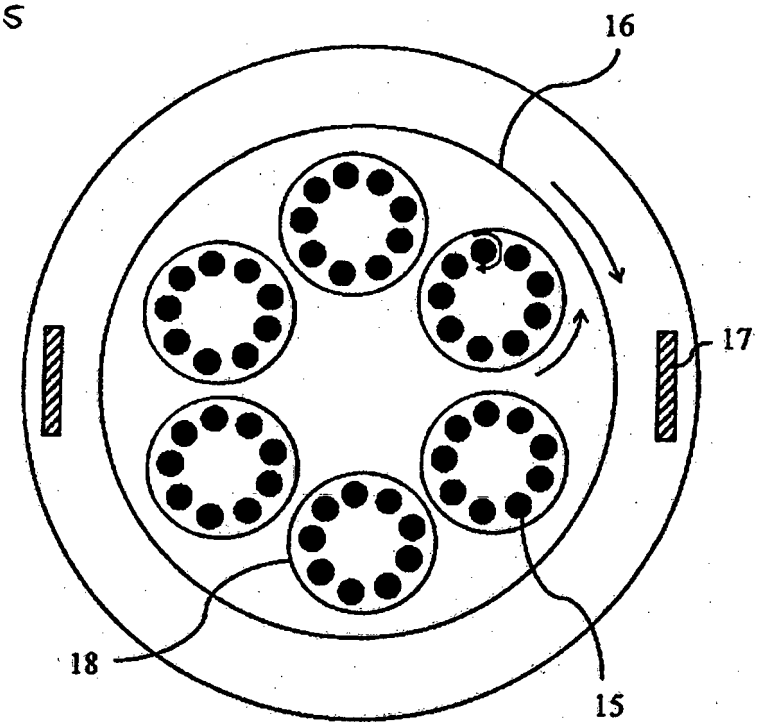


Fig. 6

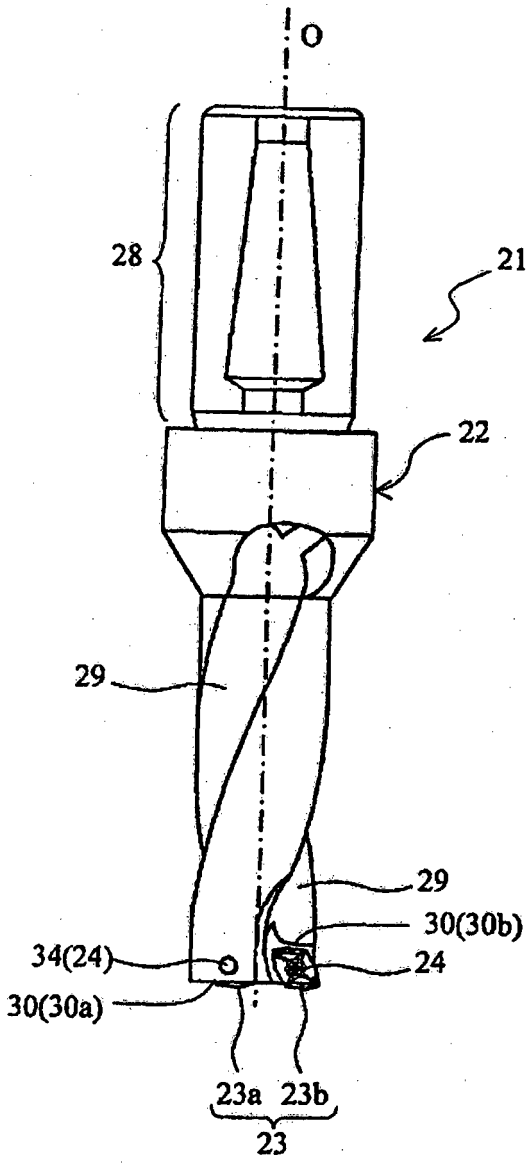


Fig. 7

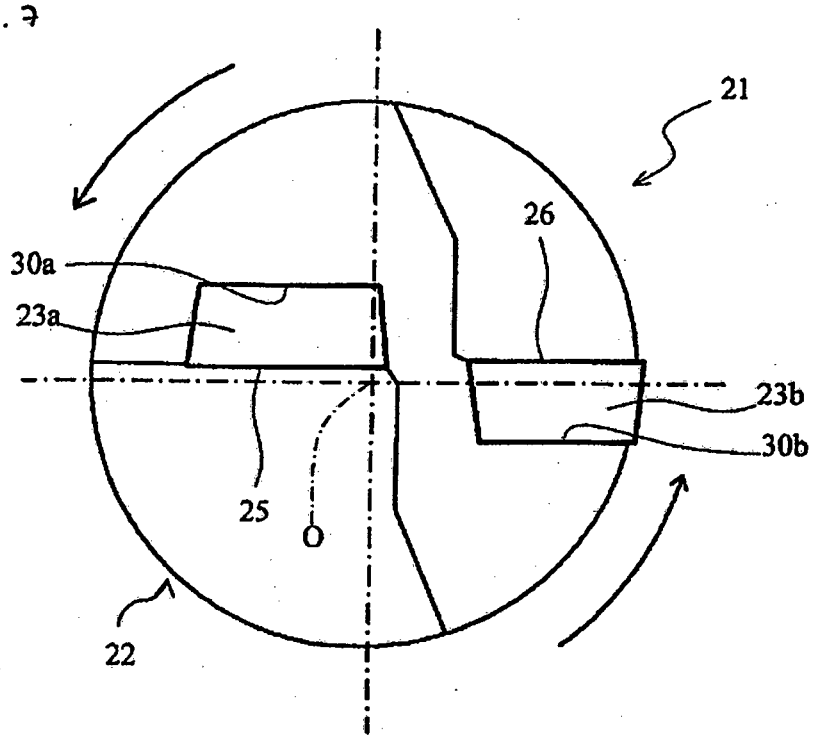


Fig. 8

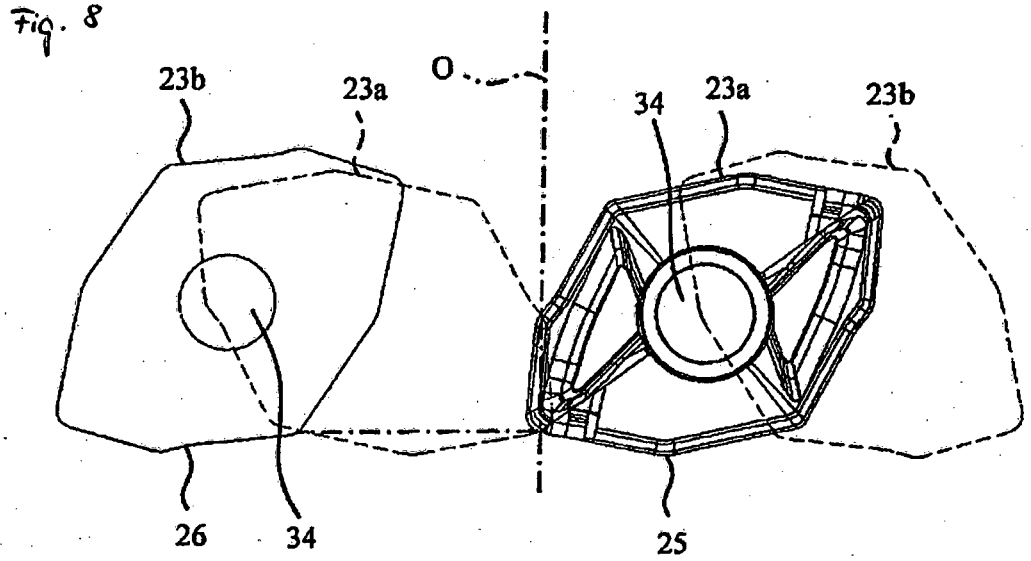


Fig. 9

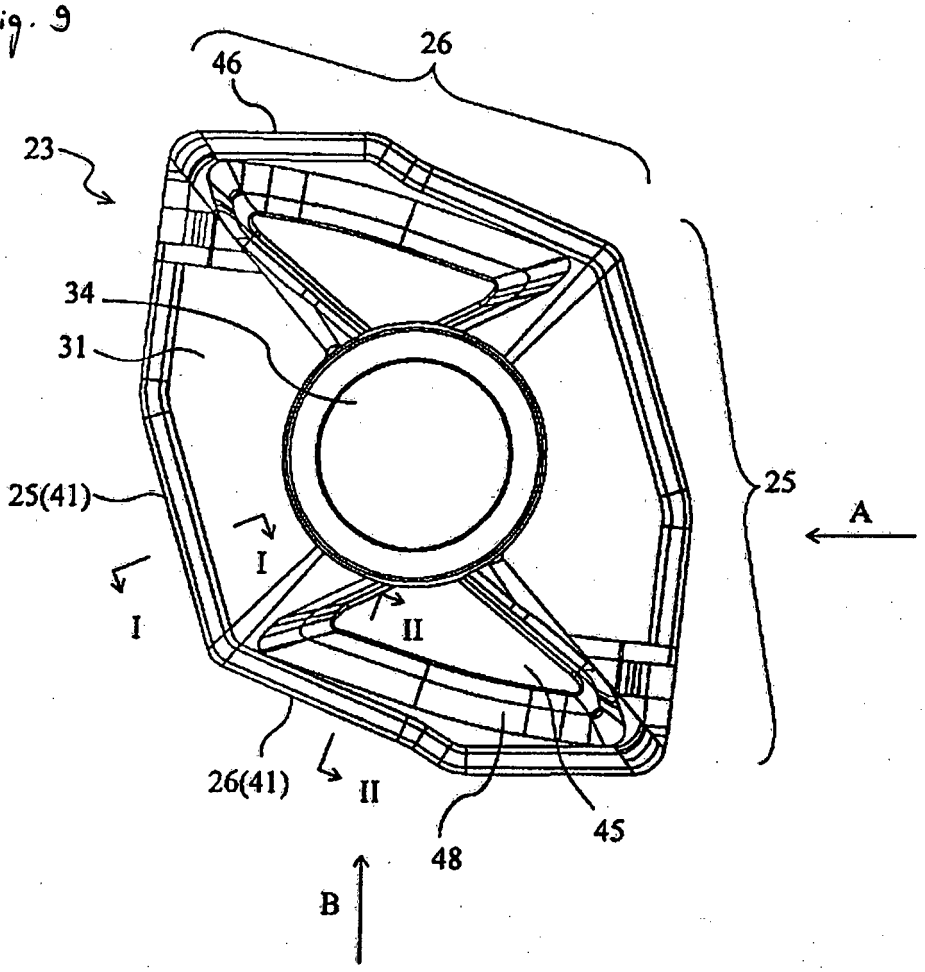


Fig. 10

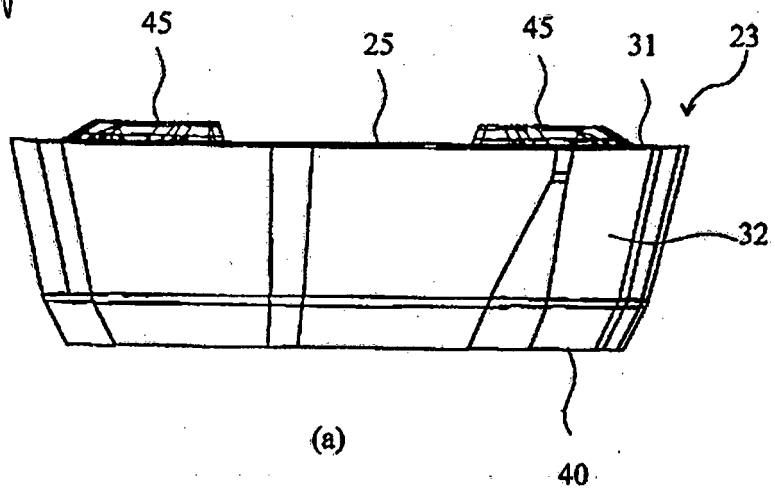


Fig. 11

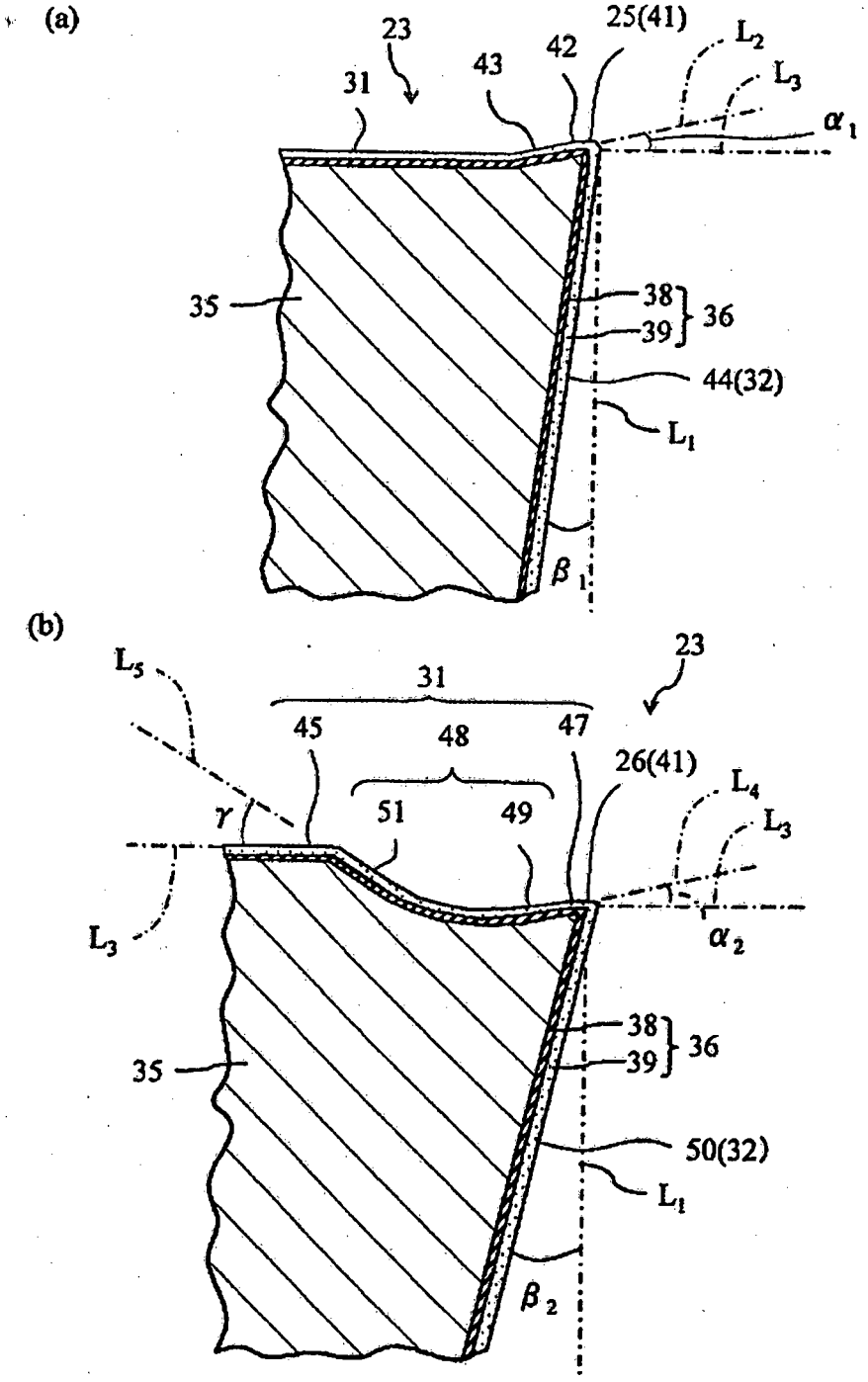

(a)
23
31
43
42
25(41)
L2
L3
α1
35
38
39
36
44(32)
L1
β1
(b)
L5
31
23
45
48
47
26(41)
L4
L3
γ
51
49
L3
α2
35
38
39
36
50(32)
L1
β2

Fig. 12

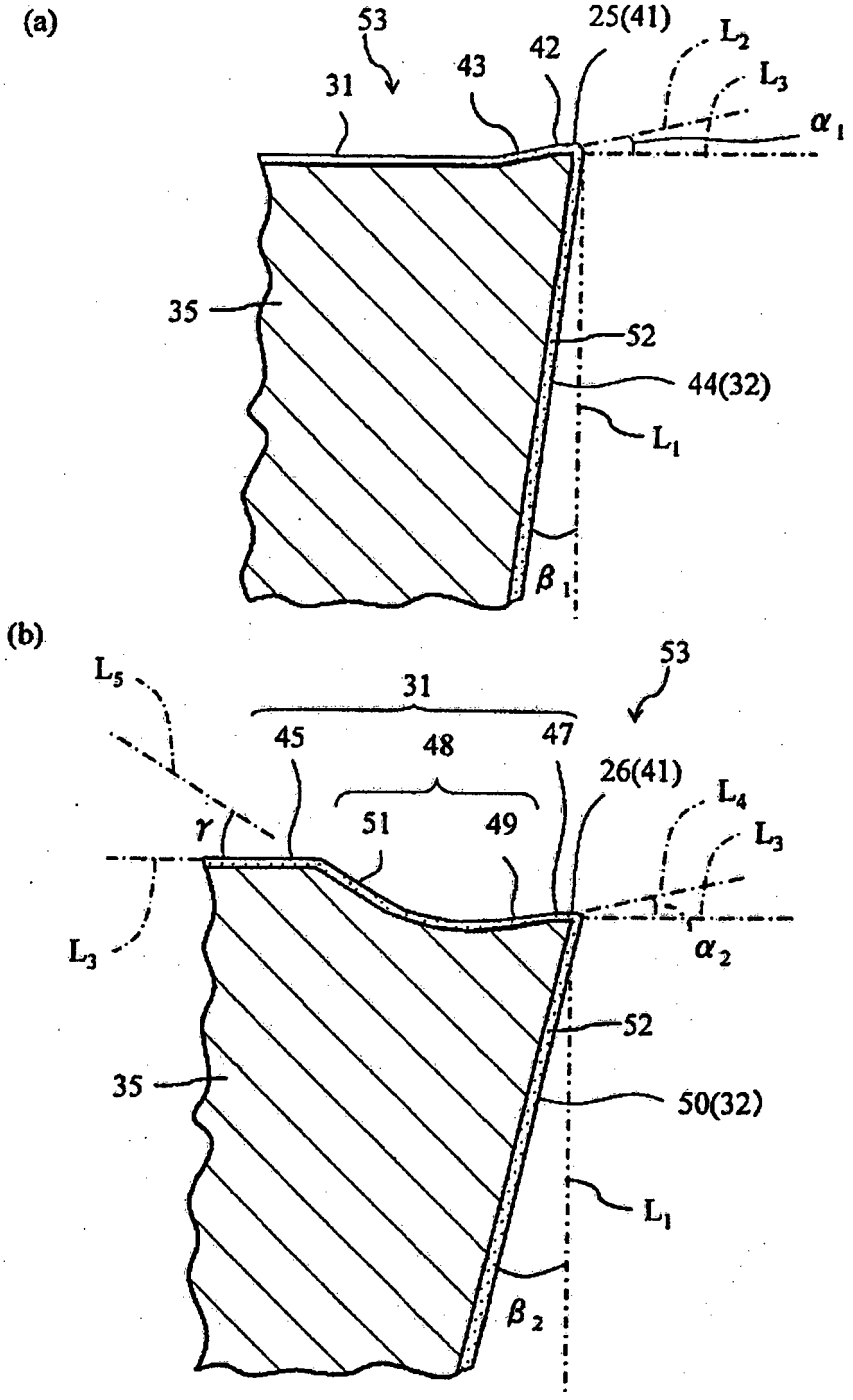
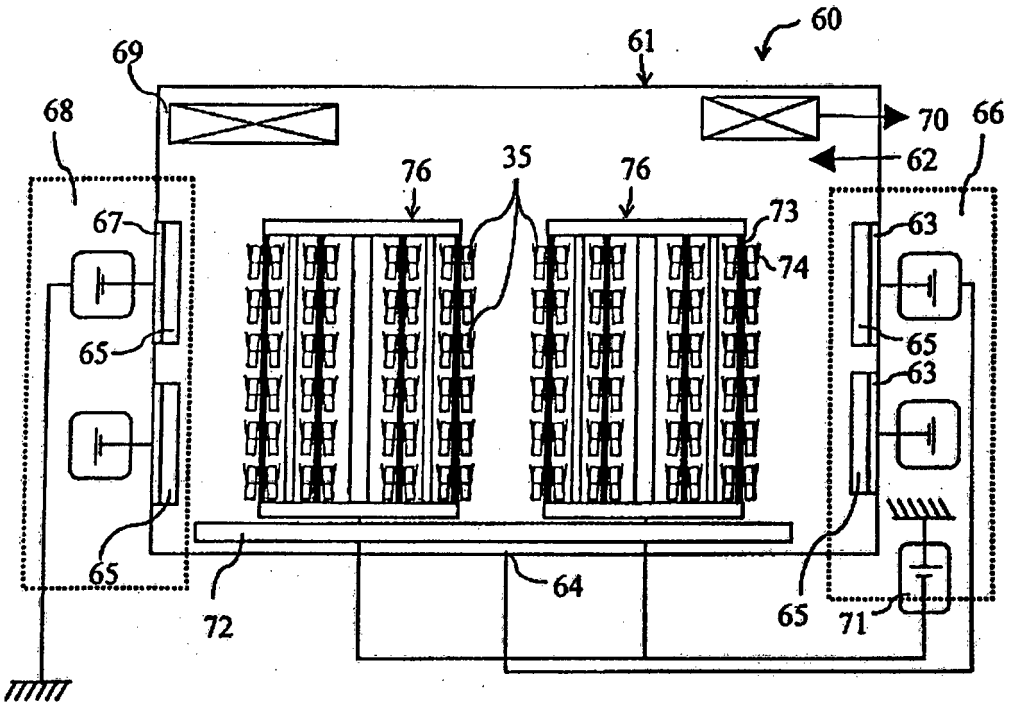

(a)
53
25(41)
42
43
31
L_2
L_3
α_1
35
52
44(32)
L_1
β_1
(b)
L_5
31
53
45
48
47
26(41)
L_4
L_3
γ
51
49
L_3
α_2
52
35
50(32)
L_1
β_2

Fig. 13



REFERENCES CITED IN THE DESCRIPTION

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